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PROCEEDINGS

of the

Indiana Academy of Science

Founded December 29, 1885

VOLUME 47

PAUL WEATHERWAX, EDITOR

Field Meeting held at
Indiana University Biological Station, Winona Lake
May 21, 22, 1937

Fifty-third Annual Meeting
Manchester College, North Manchester
November 4-6, 1937

INDIANAPOLIS:
WM. B. BURFORD PRINTING CO., CONTRACTOR FOR STATE PRINTING AND BINDING
1 9 3 8

Copies of the Proceedings may be purchased through the secretary of the Academy at $3.00 per volume

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OFFICERS AND COMMITTEES, 1937

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EXECUTIVE COMMITTEE

(Past Presidents, Officers, Divisional Chairmen, and Chairmen of Standing Committees)

Allyn, W. P.; Andrews, F. M.; Arthur, J. C.; Behrens, C. A.; Black, Glenn A.; Blanchard, W. M.; Blatchley, W. S.; Bruner, H. L.; Burrage, S.; Butler, A. W.; Cogshall, W. A.; Coulter, Stanley; Cumings, E. R.; Davis, J. J.; Deam, C. C.; Enders, H. E.; Foley, A. L.; Friesner, R. C.; Guernsey, E. Y.; Hightower, P. R.; Hessler, R.; Kintner, E.; Lyon, Jr., M. W.; Mahin, E. G.; Martin, E. S.; Montgomery, B. E.; Morgan, W. P.; Moenkhaus, W. J.; Mottier, D. M.; Naylor, J. P.; Noyes, W. A.; Payne, F.; Malott, C. A.; Perkins, Leroy; Porter, C. L.; Potzger, J. E.; Powell, H. M.; Ramsey, R. R.; Rettger, L. J.; Robbins, C. K.; Scott, Will; Steinbach, L. I.; Test, L. A.; Wade, F. B.; Wallace, F. N.; Weatherwax, Paul; Wilkinson, P. D.; Witmer, S. W.; Wright, J. S.

STANDING COMMITTEES

(Appointed by the President; first named on each committee is chairman.)

Archeological Survey: E. Y. Guernsey, Eli Lilly, W. N. Logan, Glenn Black, C. A. Malott, R. E. Esarey.

Auditing: E. S. Martin, William Johnson.

Biological Survey: B. E. Montgomery, Winona Welch, C. M. Palmer, S. R. Esten, M. W. Lyon.

Library: J. E. Potzger, Will Scott, W. E. Edington, Glenn Black.

Membership: S. W. Witmer, F. E. Beghtel, M. S. Markle, L. J. Rettger, Winona Welch, G. Don Klopp, O. B. Christy, Wm. Thornbury, E. R. Martin, Theodor Just, A. R. Bechtel, C. E. Deppe, R. E. Girton, Edward Kintner, F. R. Elliott, W. J. Tinkle, Henry Nester.

Program: Leslie Steinbach, J. C. Nelson, J. E. Williams, W. J. Tinkle, G. H. Evans.

Publication of Proceedings: J. J. Davis, C. E. Behrens, E. R. Smith, F. B. Wade, M. E. Hufford, Paul Weatherwax.

Relation of Academy to State: F. N. Wallace, J. S. Wright, Stanley Coulter, Will Scott.

Research: A. L. Foley, J. S. Wright, E. G. Mahin, W. E. Edington, R. B. Abbott.

Representative on A.A.A.S. Council: H. E. Enders.

Nominations: To be announced later.

Junior Academy of Science: H. E. Enders, F. B. Wade, O. B. Christy, W. P. Allyn.

MEETING OF THE COUNCIL

LAFAYETTE, INDIANA, MARCH 7, 1937.

The meeting was called to order by President Edington, in the Faculty Lounge of the Union Building, at 1:30 P. M., with the following members present: W. P. Allyn, W. M. Blanchard, Glenn A. Black, A. W. Butler, J. J. Davis, W. E. Edington, H. E. Enders, A. L. Foley, R. C. Friesner, P. R. Hightower, C. A. Malott, S. E. Martin, B. E. Montgomery, W. P. Morgan, W. L. Perkins, C. L. Porter, H. M. Powell, C. K. Robbins, Will Scott, L. I. Steinbach, L. A. Test, F. B. Wade, Paul Weatherwax, and P. D. Wilkinson.

Committees reported as follows:

Auditing:—Mr. Martin stated the Treasurer's report was correct and his report was approved.

The Treasurer reported that the state had granted an appropriation of $1500, $1000 to be used for publication of the proceedings and $500 for binding. It was estimated that the material now in the library could be bound in three years with such an appropriation. Dr. Friesner made a motion, amended by Dr. Butler, that Miss Nellie Coats be made a member of the Academy and be a member of the Library Committee as long as she is librarian. The motion carried.

Publication of Proceedings:—Dr. Weatherwax reported that the manuscript was about ready for the printer. He asked the Academy to appropriate $200 to cover expense of publication not taken care of by the $1000 appropriated by the state. This amount was voted. He stated that a list of the entire membership of the Academy will be published this year but only new members will be published for the next four or five years. This report was received and approved. The Editor asked if the meetings of the Entomologists and Botanists which are held at the same time as the fall Academy meeting should be published in the proceedings. Consent was given that this be done.

The Editor also asked that the State Library be made headquarters for the Academy. Consent was given.

It was suggested that each author in the Biological Division abstract his own paper and send to the editor who in turn will send it to the editor of Biological Abstracts.

Science Service has suggested that papers too long to be printed in the Proceedings be abstracted for publication and the entire paper deposited with them. They would then undertake to furnish photographic copies to anyone who might care for the entire paper. This suggestion was by consent left with the Publication Committee. It was also suggested that if the entire paper is not published in the Proceedings, the abstract of the paper handed to the division chairman be published in the Proceedings. This suggestion was referred to the committee for Program Improvement.

The Editor asked for suggestions on the publication of the Proceedings.

A motion was made that the Executive Committee express to the Committee on Relations of the Academy to the State its appreciation of the Committee's work in securing the appropriation of $1500 from the State Legislature for the work of the Academy. Motion carried.

Research Committee:—Dr. Foley asked how much money was available, no money having been reported paid out and no reports received from those to whom the grants were made. Dr. Morgan reported $150 was paid out last year, $100 coming from the A.A.A.S. and $50 from the Academy. This year, we are informed, the A.A.A.S. grant will be $125. Prof. Wade reported that the income from the Academy Foundation fund is now about $230 per annum. The Secretary was instructed to ask that the A.A.A.S. grant be sent direct to the Treasurer so that he may have a complete record of all funds. A motion was made and carried that the Research Committee recommend and transmit to the secretary of the Academy the names of grantees with the subjects of their investigation and the amount granted each and that the secretary in turn transmit this information to the A.A.A.S. with the request that the check for the amount be sent to the Treasurer of the Academy. The same procedure was also to apply to the Foundation funds.

New Business:—The President announced the appointment of a committee to co-operate with the Indianapolis committee arranging for the A.A.A.S. meeting next winter. The following were appointed on this committee: A. W. Butler[1], Chairman; F. B. Wade, Vice-Chairman; T. E. Mason, R. R. Ramsey, W. M. Blanchard, S. S. Visher, C. A. Malott, J. J. Davis, F. Payne, H. G. Nester, M. S. Markle, H. R. Kraybill, F. D. Brooks, W. M. Lyon, Jr.; A. A. Potter, T. M. Bushnell, S. E. Perkins, III.

In answer to a question of an Academy exhibit at the time of the A.A.A.S. meeting a motion was carried to appoint a committee to consider the question of an exhibit, and if attempted, the nature of the exhibit.

A motion that the officers of the Academy present annually an estimate of their probable expenditures was tabled.

The question of the taxation of the Academy funds under the new laws was raised and Prof. Wade was asked to investigate.

The following committee on Program Improvement was announced by the Chairman: R. C. Friesner, Chairman; J. J. Davis, E. R. Smith, F. J. Allen, W. P. Allyn, H. M. Powell, Glenn Black, J. B. Dutcher, R. C. Davis.

The Chairman announced that Dean Howard E. Enders had been appointed to represent the Indiana Academy of Science at the inauguration of Dr. Clyde Everett Wildman as President of DePauw University on March 10, 1937.

Adjourned 4:00 p. m.

L. A. TEST, *Secretary.*

[1] Walter G. Gingery was later made co-chairman with F. B. Wade in place of A. W. Butler, deceased.

MINUTES OF THE SPRING MEETING

The business session of the Spring meeting was called to order by President Edington in the dining room of the Westminster Hotel at Winona Lake, May 21, 1937, at 7:30 p. m.

Professor Friesner presented the report of the committee on Improvement of Program. Action was postponed until the fall meeting.

President Edington brought up the question of the possibility of the state high school teachers' being excused from their work so that they might attend the fall meeting of the Academy, placing it on the same basis as the State Teachers Association. He suggested that the matter be taken up with the State Superintendent of Public Instruction. A motion was passed that the President appoint a committee of three to take up the matter with the Superintendent of Public Instruction and report at the fall meeting. Professor E. R. Smith of DePauw University was made chairman of this committee.

A motion was passed that a committee be appointed to prepare exhibits for the Academy and the Junior Academy, at the time of the meeting of the American Association for the Advancement of Science in Indianapolis this fall. This committee consists of S. E. Perkins III, N. E. Pearson, O. B. Christy, C. L. Porter, and C. O. Pauley.

The date for the fall meeting was discussed and the second or third week end in November seemed to be preferred.

A motion by John S. Wright that an amount up to $50 be paid from the Academy funds for the use of the Exhibit Committee was carried.

Dr. Weatherwax spoke briefly of the progress of the printing of the Proceedings and urged that all proof be returned as promptly as possible. He stated that the Proceeding would be smaller than last year.

It was suggested that the names of section chairmen be sent out with the preliminary notices next fall so that authors might know to whom to send their abstracts.

Professor Kintner, Chairman of the Program Committee, spoke briefly of the program for the meeting.

The evening's program was then carried out as scheduled.

About 40 turned out for the bird hike Saturday morning, but the rest of the day's activities were more or less spoiled by rain.

PROGRAM OF THE WINTER MEETING

MANCHESTER COLLEGE, NORTH MANCHESTER

NOVEMBER 4-6, 1937

THURSDAY, NOVEMBER 4

7:30 p. m. Meeting of the Executive Committee.

FRIDAY, NOVEMBER 5

9:30 a. m. General Session.

Music—Cantilena Choir, Manchester College.

Address of Welcome—President Otho Winger, Manchester College.

Response for the Academy—President Will E. Edington.

Business Session.

Necrology—Read by Dean Emeritus Stanley Coulter, Purdue University.

Amos W. Butler
John B. Dutcher
Stacy O. Hawkins
R. E. Nelson
Will E. Scott

"Regional contrast in rainfall intensity in Indiana and some effects thereof."

S. S. Visher, Indiana University.

"Notes on a suggested treatment for fall hay fever."

Ernest Rice Smith, DePauw University.

11:00 a.m. Sectional Meetings. For programs of the sections see: archeology, p. 46; bacteriology, p. 58; botany, p. 71; chemistry, p. 115; geology and geography, p. 143; mathematics, p. 189; physics, p. 192; psychology, p. 212; zoology, p. 226.

12:15 p. m. Luncheon.

1:30 p. m. Sectional meetings continued.

4:30 p. m. Tea for members of the Academy and their guests through the courtesy of the Faculty of the College.

6:30 p. m. Annual Dinner.

Business Session.

Music—Madrigal Club, Manchester College.

Colored Motion Photomicrography Film "The Formation of Crystals,"

Kent H. Bracewell, Hamline University.

President's Address—"Science and Modern Thought."

Will E. Edington, DePauw University.

SATURDAY, NOVEMBER 6

9:00 a. m. Junior Academy of Science, Business meeting and exhibits. See page 311.

9:00 a. m. Entomologists' meeting. See page 315.

9:00 a. m. Taxonomists' meeting. See page 315.

1:00 p. m. Program of Junior Academy. See page 311.

2:00 p. m. Football game—Manchester College vs. Albion College, Michigan. Members of the Academy and of the Junior Academy were invited to see the game as guests of the College.

MINUTES OF THE EXECUTIVE COMMITTEE

MANCHESTER COLLEGE

NOVEMBER 4, 1937

The meeting was called to order at 7:30 p. m. by President Edington. The minutes of the Executive Committee for March 7, 1937, were read and approved, as were the minutes of the spring meeting, held at Winona Lake, May 21, 1937.

Officers and Committees reported as follows:

Academy Foundation. Chairman Frank B. Wade reported as follows as of November 1, 1937:

Receipts

Balance from previous year	$ 165.08
Interest on investments	259.46
Sale of $500.00 N. Y. Central R. R. Bond	570.03
From a friend of the Academy	500.00
Total	$1,494.57

Expenditures

Withdrawal from bank for purchase of $500.00 N. Y. Central R. R. Bond	$ 565.46
Purchase of $500.00 U. S. Treas. Bond	577.10
Total	$1,142.56
Balance in bank	$ 352.01

Present Assets at Par Value

U. S. Treas. Bonds	$4,700.00
Cons. Fed. Farm Loan Bonds	1,500.00
Common Stock S. Oil Co. Ind.	150.00
Pref. Stock Muncie Masonic Temple	200.00
Total	$6,550.00
Total market value of funds (approx.)	$7,067.00

Archeological Survey. An informal report was given by Glenn A. Black in the absence of Mr. Guernsey. The work last summer was a

continuation of that carried on during the previous summers in the northern and southern parts of the state.

Auditing Committee. Mr. Martin stated that no report could be given at this time since the Academy year does not close until December 31. The books for last year were correct and in excellent shape. Mr. Wade asked that the Auditor check the books of the Trustees.

Biological Survey. In the absence of the Chairman, B. E. Montgomery, Dr. M. W. Lyon read the report:

Very little work has been done on the bibliography of the Indiana Biota during the year, except that certain collaborators, especially Doctor Welch, have continued to add cards listing the titles of current papers containing references to Indiana records in their special fields. The Committee wishes to repeat the observation made last year, "Members of the committee and collaborators cannot develop much enthusiasm in the preparation of a manuscript which must wait indefinitely for publication and which, in the meantime, requires constant revision to include new titles as they appear." However, it may be noted that the bibliography could probably be completed within a short time if any definite plan for publication were adopted.

The status of Deam's flora of Indiana and Montgomery's Odonata of Indiana is the same as last year; both are practically complete.

Investigations on the fauna and flora of the state by members of the Committee and others have continued. Dr. Welch spent several weeks in the field, collecting mosses and liverworts in 21 counties. A report of her records is included in the program of the present meeting of the Academy. In addition to bryophytes she collected a few algae, which were forwarded to Dr. Palmer, and some lichens, which were determined by Dr. Raymond Torrey of New York and returned to the DePauw Herbarium. Three undergraduate students at Purdue University have selected investigations on certain insect groups in Indiana as thesis subjects and have begun the compilation of published records and the collection of material. These are Ralph Morris, working on the Formicidae, or ants, Bernard P. Kolkana, on the Culicidae, or mosquitoes, and Philip Luginbill, Jr., on the Orthoptera, or grasshoppers. The manuscript of a similar work on one of the subfamilies of leaf hoppers, made by Harry E. Brown two years ago, is now in process of publication.

The Committee recommends, as it has done for several years, that the Academy call to the attention of the officials and citizens of the state the desirability of building a fire-proof museum for the storage of scientific specimens which have been collected in Indiana or elsewhere, so that they may be available to scientists of the state for study. Many of our sister states, notably Illinois, Michigan, and Ohio, have excellent facilities for the preservation and study of scientific specimens. Much valuable material has been sent out of the state because of the lack of a suitable place for its preservation here and this loss will continue until an adequate museum is established. The committee notes with satisfaction that arrangements for the permanent preservation within the state of the Deam and Blatchley collections have been made within the last few years. If adequate funds for a museum building could be furnished to the state universities or to an independent research museum, enough material would soon be secured to place Indiana on a level with neighboring states.

A motion was made by Dr. Lyon that the Secretary correspond with the state officials and call attention of the public to the need for a fire-proof State Museum. This motion was amended by Dr. Potzger to read that a committee be appointed to take charge of this matter. Motion carried as amended.

Bonding Committee. Dr. Bruner reported that notice of the annual premium for the bonding of the Trustees of the Academy Foundation had been forwarded to the Treasurer. The bonded Trustees include the Treasurer and two other Trustees elected by the Executive Committee for a period of four years. According to the conditions of

election, the term of service of Trustee John S. Wright expired in 1936. A motion to refer the matter of a successor to Mr. Wright to the nominating committee was carried.

Editor. Dr. Weatherwax, as Editor, reported as follows:

Volume 46 of the Proceedings, which was delivered to the State Library for distribution early in September, consisted of 282 pages. The edition was increased 100 copies over that of last year; of the 1600 copies printed, 1000 were bound in cloth and 600 in paper covers.

The total cost of manufacture of the volume and the reprints was $1421.89. Of this amount, $421.89 was paid by the Academy, and $1000 by the state. From authors of reprints, will be returned $157.09, and $73.84 is chargeable to the Academy for reprints of memorials and the membership list and for reprints furnished free to authors. The net cost to the Academy was $190.96. The cost of the volume per printed page was $4.135. Certain changes in arrangement and in style of type have increased slightly the average amount of material per printed page.

One hundred reprints of the necrology have been prepared for distribution to authors of memorials and members of the families of the deceased. Five hundred reprints of the membership list were also prepared. By issuing these to new members and publishing changes in membership each year, the publication of the complete list of members can be postponed for several years.

Dr. Enders moved that the list of Junior Academies be published each year in the Proceedings. Motion Carried.

Library Committee. Dr. Potzger read the following report:

Your Library Committee had little occasion to display great activity during the past year. The affairs of the library are at a stage where the efficient service of Miss Coats meets the current problems. Her report to the Committee presents the most vital problems before us:

"The Indiana Academy of Science Library is now receiving some 279 serials regularly in exchange for the Indiana Academy Proceedings, sent to 234 institutions and learned societies, 93 of which are American, 141 of which are foreign. Eleven new titles have been added since the last report made in May.

"Some progress is being made with the binding. Four-hundred forty-five volumes will be bound within the next few weeks at an estimated cost of $500.00. Something like 500 more volumes are ready and should be bound very soon if some method can be found for financing the work. Additional volumes should be bound also if funds can be supplied for purchasing the numbers necessary to complete them. Many numbers have been furnished by the issuing agencies but some are out of print and are no longer available there. It is hoped that this year we may enter into exchange agreements with a longer list of scientific societies and institutions and thus increase the number of publications received by the library.

"There is in process of compilation at the present time a union list of the serials in some 40 Indiana libraries, and your librarian is adding to this check list the titles owned by the Academy of Science. The inclusion of these titles in a general list available in most libraries should greatly increase their usefulness."

It might be well to add to my report here the cardinal points of the May letter to the Academy.

Of the 28 Academies of various states, 17 were sending material to our library. Four of the non-exchanging academies issued publications which would in the future be sent on exchange. These are: Minnesota Academy of Science, New York Academy of Science, Ohio Journal of Science, South Carolina Academy of Science. Thirty new titles were added from other scientific institutions and societies.

A motion by Dr. Coulter that a vote of thanks be given to Miss Coats for her efficient work in the Academy was passed.

Membership Committee. Dr. Witmer submitted a summary of new members for last year stating the numbers interested in each of the various branches of Science:

This report is, in part, a review of the applications of the new members elected last year. Each prospective member indicates on the application blank the department of science in which he is interested or engaged. Last year the following departments were included: Mathematics, Bacteriology, Physiology, Entomology, Chemistry, Geology, Physics, Mammalogy, Biology, Psychology, Botany, Anthropology, General Science, Nature Study, Metallurgy, Genetics, Geography and Ecology. This list is presented for the purpose of giving some idea of the range of departments touched in one way or another by the activities of the Academy.

This year the membership committee is still, at this point, making up its new list of applications. At this moment we have in hand some 31 applications. The chairman will be available between sessions to receive any additional applications that are still unreported. He is also able to supply application blanks to those who intend to use them.

Press Secretary. Dr. M. W. Lyon, Jr. made the following report:

During the year the Press Secretary sent in three reports of meetings to SCIENCE which were published. To the same journal he sent death notices of two of our past presidents, Amos Butler and Will Scott, and wrote a brief obituary of Amos Butler for the JOURNAL OF MAMMALOGY, of which Butler was one of the founders.

Not knowing what arrangements had been made at the previous meeting, he also sent several telegrams to various important papers regarding the election of new officers and the meeting place for this year.

At the time of the Spring Meeting the Press Secretary was ill, and asked the publicity agent of Indiana University to get out suitable press notices as the meeting was being held at the Summer School of the University, and the late Dr. Scott was in charge of the scientific work.

The Press Secretary recommends that, during the periods of the Academy's activity, subscription be made to a news-clipping agency in order to find out whether newspapers pay any attention to his reports. These clippings, if any, could be turned over to Professor Edington to file with his other historic documents.

Program Committee. Professor Kintner spoke of the difficulty of knowing just what arrangements were necessary and how many programs are needed. At his suggestion a motion was made and carried that a committee of three be appointed to formulate suggestions for the work of committee chairmen and division chairmen and for other officers as needed.

It was moved and carried that the programs of the meetings be sent before the meetings, by the Press Secretary, to various papers of the state.

Publications of Proceedings. The report was read by Dr. Weatherwax and contained a number of important suggestions:

Your Committee on Publication of Proceedings begs leave to submit the following recommendations:

1. That the status of the Editor be changed by making this office appointive, the appointment to be made annually by the officers of the Academy (i. e. the Council) at the Annual Meeting of the Academy.

2. That the Committee on Publication of Proceedings be nominated by the Nominating Committee after consultation with the Editor, such committee to include representatives of each branch of science represented on the Academy program. Papers submitted for publication may, at the discretion of the Editor, be referred to the qualified member of the Publication of Proceedings Committee to determine their qualification for publication in the Proceedings. This suggestion, if approved, will necessarily increase the size of the committee to include a representative of each science division of the Academy, at present nine.

3. That the Academy appropriate annually a sum, not to exceed $200.00, for use by the Editor for the employment of qualified assistance.

4. That the Proceedings include abstracts of papers not to be published in full in the Proceedings, and, so far as possible, a citation given of the place of publication or probable place of publication of the complete paper.

5. That the Editor arrange with Science Service for their services, which provide for the deposition of complete copies, including tables, graphs, etc., for papers too long or with too large number of tables for publication in the Proceedings. Film strip copies of such papers will be furnished by Science Service to anyone requesting same, at a nominal

cost. It is understood that an abstract of papers deposited with Science Service will be published in the Proceedings and the availability of the complete paper through Science Service noted.

6. Your committee reiterates its previous ruling that papers submitted to the Academy for publication in the Proceedings must not be submitted to other technical publications; also that papers submitted for publication to a technical publication not be submitted for use in the Academy Proceedings. Any infringement on this ruling will necessitate definite citation.

It was moved and carried that the Editor be granted $200.00 for use in hiring necessary clerical help.

The report of the Publication Committee was approved and it was voted that this committee have a copy of its report sent to each member of the Executive Committee, these recommendations to be voted upon at the spring meeting.

Relations of the Academy to the State. Mr. Frank N. Wallace presented a brief report regarding the appropriation which the committee had secured from the State Legislature:

Your Committee begs to report that they made a request of the Budget Committee for an appropriation of $3,000.00 as per the instructions of the Academy. The Budget Committee would not recommend $3,000.00 but did put in $2,000.00. The House of Representatives cut this to $1,500.00 and this amount was to print our Proceedings and pay for the binding of the papers belonging to the Academy. I wish to thank the members of the Committee for their very great assistance and also thank Mr. Virgil M. Simmons for his valuable help in securing the $1,500.00.

Research Committee. Dr. Foley made a brief report on the grants made last year.

A grant of $75.00 was voted to Dr. Ira T. Wilson of Heidelberg College, Tiffin, Ohio, for work to be done on sedimentation in the lakes of northern Indiana. The committee wants it made clear that it is not establishing a precedent in making this grant to one connected with a college outside of Indiana.

Dr. Winona Welch, Associate Professor of Botany, DePauw University, was granted $100 for a continuation of her studies of Indiana bryophytes. Her field trips covered a distance of 1870 miles, yielded 2080 packets of mosses and liverworts, and 11 new species and varieties. To date Miss Welch has expended but half her grant, reserving the remainder for field trips during the late winter and spring to study species that do not fruit during the summer months. A partial report of her work was presented at the last meeting of the Academy and has been published in this year's Proceedings. She expects to publish a complete report a year hence.

A grant of $50 was made to Scott McCoy, an independent botanist of Indianapolis. To date he has expended but $17.92 of his grant. He has run a total of 1290 10 x 10-meter quadrats in Jennings County forests, and has located other type forests in Jennings, Jefferson, Jackson, and other counties in the southeastern lobe of the Illinoian area. He has taken 66 soil samples at surface, 3-inch, and 12-inch levels, and expects to make a "sociological study of the flora."

A grant of $50 was made to Assistant Professor C. M. Palmer, of Butler University, for a study of the distribution of Lemanea in southern Indiana. A full account of the results of the study is to be presented at this meeting of the Academy and will be published in the Academy Proceedings. Mr. Palmer worked in 28 counties, traveled 2430 miles, and found Lemanea in 65 locations in 16 counties. He discovered an interesting and unsuspected relation between Lemanea and geological formations.

A grant of $50 was made to Professor R. E. Martin, of Hanover College, for a study of the minimum stopping distances of cars with modern tires and on modern roads. A full report of the work is presented at this Academy meeting and will be published in the Academy Proceedings. In general, Mr. Martin found that the stopping distance is greater than that claimed by some manufacturers and very much greater than that many automobile salesmen would have their customers believe is possible, an exaggeration that is partly responsible for the frightful auto death toll.

Treasurer. The complete report was deferred until the end of the fiscal year, December 31. The following report was later made by Treasurer Morgan and approved by the Auditing Committee:

Receipts

Balance on hand January 1, 1937	$ 753.20	
Dues and initiation fees collected	839.00	
A.A.A.S. Refund for Research Grants	125.00	
Author's Reprints Vol. 45	19.87	
Author's Reprints Vol. 46	148.21	
		$1,885.28

Disbursements

1—Program Committee	$ 107.25	
2—Expenses of Editor	94.08	
3—Expenses of Secretary	26.72	
4—Expenses of Treasurer	51.00	
5—Mailing Proceedings	112.22	
6—Expenses Press Secretary	23.24	
7—Stationery	52.04	
8—Indianapolis Engraving Co.	176.21	
9—Fort Wayne Printing Co.	170.53	
10—Junior Academy Bulletins	20.00	
11—Surety Bonds and Safety Deposit Box	20.50	
12—Research Grant	100.00	
13—Expense Refund to Officers and Chairmen	12.13	
14—Funeral Floral Memorials	10.35	
15—Expense Fund Local A.A.A.S. Meeting	100.00	
		$1,076.27
Bank Balance		809.01
		$1,885.28

Junior Academy. Dr. Enders made the report:

Your committee on the Junior Academy of Science has continued in touch with 28 active clubs of last year and has endeavored to stimulate them to high accomplishment by correspondence and circulation of the Science Club Service, published by Louis Astell, and made available by the payment of $20.00 by the Academy for this purpose.

In preparation for our meeting this week, your chairman has sent out 75 letters of invitation to principals of high schools, whose clubs are not now affiliated with the Junior Academy. The letter related the history of the Indiana Junior Academy of Science and set forth the effectiveness of the stimulus that other science clubs have received by their affiliation with it. Special attention was directed to the striking exhibits and demonstrations and the program by members of the Junior Academy at its Saturday sessions. The principals were urged to bring the matter to the attention of their most aggressive science club leaders and to encourage them and a few of their club members to attend the Saturday sessions, where they may have an opportunity to observe what is accomplished by the affiliated clubs.

We expect to have seven or more new clubs for proposal to membership at this session. In nearly every instance the new club membership brings with it the application of the sponsor to membership in the Indiana Academy of Science. The new proposals will raise the membership of the Junior Academy from 28 to a number somewhat less than 40.

We have reason to believe that the Academy has rendered a valuable service within the state by cooperating with the Illinois Academy of Science and other academies in the publication of the *Science Club Service*, a small publication of source material for the affiliated academy clubs. We recommend that the Indiana Academy of Science again approve an allotment of $20.00 toward the co-operative publication in 1937-38 of the *Science Club Service* under the direction of Mr. Louis Astell, Urbana, Illinois. Copies of the publication, as they are issued, are supplied the active and prospective clubs. The DuPont de Nemours Company has made up a circulating exhibit, to be used by high school

clubs, on the production and use of the synthetic rubber originated by our deceased Past President Nieuwland. Duplicate exhibits are to be made available for circulation among our clubs. We have reason to believe that we may secure a similar exhibit and program material in plastics and textiles from the same concern.

An article by Robert Littell in the October number of the *Readers Digest*, under the title, "Staying After School For Fun," grew out of the participation of your chairman in the broadcast at Atlantic City, last December, on the Student Youth Movement, in which he emphasized the dearth of source material for use of Junior Academy of Science Clubs in the preparation of their programs. The response of the DuPont Company was stimulated by the same broadcast.

The Junior Academy exhibits and program are scheduled for Saturday morning and afternoon. We urge as many members of the Academy as possible to attend these sessions, particularly to view the exhibits of the clubs which will be installed on Saturday morning. Last year about 20 clubs were represented at the meeting, and 160 Junior Academy members and sponsors were present at the sessions. The exhibits and the program this year will excel those of former years. We are eager, therefore, to have members of the Indiana Academy of Science show their interest in this phase of the work of your committee.

It was voted that $20.00 be turned over by the treasurer of the Academy for the work of the Junior Academy.

Nominating Committee. Dr. Enders reported the following nominations for fellows of the Academy: Glenn A. Black, Eli Lilly, S. E. Perkins III, Frank N. Wallace. Dr. E. G. Mahin was nominated to succeed himself on the Research Committee for a term of five years, and Dr. Ray C. Friesner to same committee for two years, filling out the unexpired term of C. C. Deam who resigned. Mr. John S. Wright was nominated for reelection to the Board of Trustees, term to expire in 1940. All were elected.

Program Improvement. (Special Committee.) The report was presented by Dr. Friesner and, after discussion and amendments, was finally adopted in the following form:

1. The committee feels that two actions taken at the Danville meetings of the Academy will be likely to result in improvement of the program, viz. (a) no paper will be accepted on the Academy program to be "read by title"; (b) an abstract of each paper must be sent to the chairman of the section before the title will be placed on the program.

2. The committee recommends that abstracts of all papers appearing on the program be published in the Proceedings regardless of where the paper itself is published.

3. Honorable mention shall be made for outstanding papers in each section, such papers to be determined by the Research Committee and names to be read at the dinner meeting.

4. We recommend that each divisional chairman present an address, not to exceed 30 minutes, before the forenoon meeting of the section over which he presides.

Excusing Teachers for Academy Meetings. Dr. E. R. Smith presented the following report:

Walter Gingery, Principal of Washington High School, Indianapolis, appeared before annual meeting of Superintendents to appeal for their encouragement to the high school teachers of science to attend meetings of the Academy. Letters, enclosing program of meeting, were written by Dr. Edington to all superintendents within 50 miles of North Manchester in towns of 1000 or over, to all to within 50-100 miles in cities of 2500 or over, and to those within 100-150 miles in cities of 5000 or over.

Co-operation with A.A.A.S. Mr. F. B. Wade reported the work well organized and the two committees working together.

Committee on Exhibits. Report given by Dr. Edington reported that the committee hoped to have on exhibit information about the Academy and some outstanding examples of the work of Academy mem-

bers. It was moved and carried that this committee be authorized to expend sufficient money to cover the expense of arranging the exhibits.

Mr. John S. Wright presented a resolution that the Treasurer pay from the Academy funds not less than $100.00 nor more than $200.00 to help with the expenses of the A.A.A.S. for the Indianapolis meeting.

All committee reports were accepted.

Meeting adjourned at 11 p. m.

MINUTES OF GENERAL SESSION

Dean Holl introduced President Winger of Manchester College, who welcomed the Academy. Dr. Edington responded briefly. The minutes of the Executive Committee were read and approved. President Edington announced a Committee on Invitations consisting of O. B. Christy, Chairman; Winona Welch, R. E. Girton, C. M. Palmer, and Theodor Just, and a Committee on Resolutions of James F. Mackell, Chairman; W. J. Tinkle and R. C. Friesner. The scheduled program for the day was then carried out.

A short business meeting followed the dinner, at which 180 were present.

Professor Witmer of the membership committee reported 70 applications for membership. All were elected.

The Resolutions Committee offered the following:

The Indiana Academy now assembled in its fifty-third annual meeting, wishes to express, in this formal way, its appreciation, individually felt by its membership, for the arrangements that have been made for its convenience and have contributed materially to the success of the meetings. It desires to express its special appreciation to President Winger for his generous welcome, to the Faculty, to the Cantilena Choir, to Professor Kintner and his Program Committee for its efficient planning of the meetings, and to the citizens of North Manchester for their hospitality in opening their homes for the comfort of the members.

The Committee on Invitations recommended that the Winter Meeting of the Academy be held at Purdue University in 1938. This recommendation was approved.

The Nominating Committee announced the election of Division Chairmen as follows: *Archeology,* Glenn A. Black; *Bacteriology,* P. A. Tetrault; *Botany,* Floyd E. Beghtel; *Chemistry,* Frank V. Graham; *Geology and Geography,* Stephen S. Visher; *Mathematics,* J. E. Dotterer; *Physics,* Seth Elliott; *Psychology,* A. R. Eikenberry; *Zoology,* H. G. Nester.

The following were nominated for officers for 1938: *President,* Eli Lilly; *Vice-President,* T. G. Yuncker; *Secretary,* William P. Allyn; *Treasurer,* W. P. Morgan; *Editor,* Paul Weatherwax; *Press Secretary,* Will E. Edington.

The Secretary was instructed to cast the unanimous ballot of the Academy for these nominees.

After a few announcements the Academy adjourned.

LOUIS A. TEST, *Secretary.*

NECROLOGY

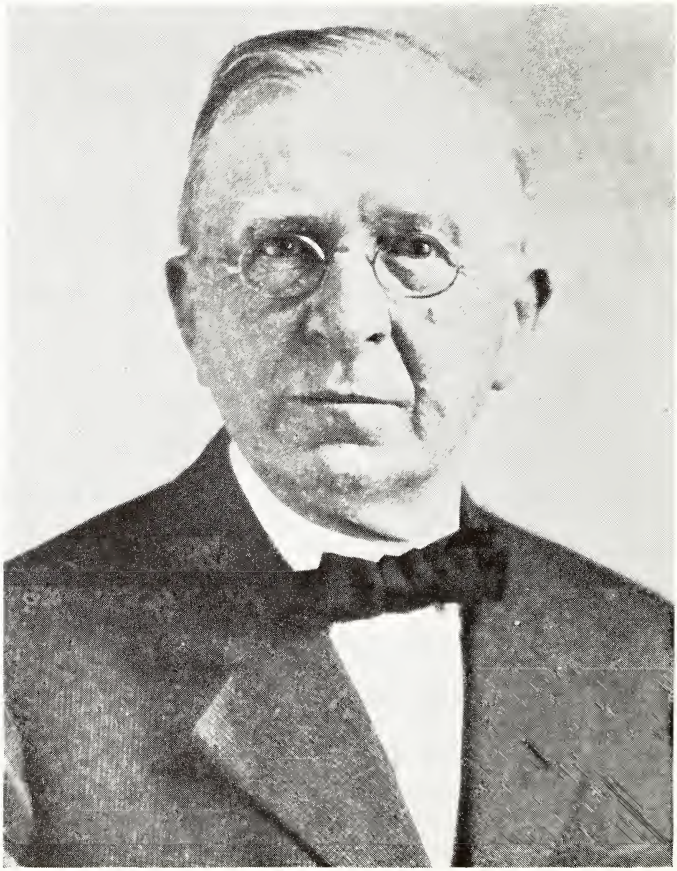
Amos William Butler

Brookville, Indiana — Indianapolis, Indiana
October 1, 1860 — August 5, 1937

At the fortieth meeting of the American Ornithologists' Union held in Chicago, October 23-26, 1922, I was introduced to a tall, dignified member of the Union. He had a kindly smile and friendly manner which captivated me. Everyone seemed to know him, and he seemed to know everyone. That member was Amos William Butler. In response to an inquiry I replied that I had been collecting plants in the Indiana Dunes all summer and in the autumn had made a collection of mammals in the same region. He asked me to write a paper on the mammals and to present it before the Indiana Academy of Science at the next meeting in December. Who could refuse the request of such a man! It was a happy introduction for me, not only to one who became a valued friend but also to the Indiana Academy of Science with nearly a thousand members, most of whom I was to know personally. It was not merely the Indiana Academy of Science, but, as I learned later, it was Butler's Indiana Academy of Science; for it was Butler who was the prime founder of the Academy, and his fine spirit, his enthusiasm, his love of exact knowledge, and above all his friendliness that made our Academy what it is.

Amos William Butler, zoologist, anthropologist, and sociologist, was born October 1, 1860, at Brookville, Indiana. His parents were among the early pioneers of southeastern Indiana. Brookville lies in the beautiful Whitewater valley. It is not far removed from Cincinnati. Both of these facts probably had a profound effect upon the young Butler. He must have been impressed by the beauties and forces of nature in that valley. Also in Cincinnati there was a group of nature lovers and a natural history society. He was educated in the local schools, including a year or more at Brookville College. Afterwards he attended Hanover College, so beautifully located on the banks of the Ohio, from which many distinguished Hoosiers have been graduated. Later he received an LL.D. from Hanover in 1915. In 1894 he received an A.B. degree from Indiana University, in 1900 an A.M., and in 1922 an LL.D. He was honored by election to Phi Beta Kappa and to Sigma Xi.

As a boy he came in contact with Rufus Haymond, one of the pioneer naturalists of the Ohio Valley, and also with Frank Langdon of Cincinnati. Under the influence of these men and others he began a collection of local birds, which afterwards was added to by collection and exchange from all parts of Indiana, various portions of the United States, and some foreign countries. At its height his collection numbered about five thousand specimens. When I saw them, they were cared for in a special, detached portion of his home in the suburb of Irvington, Indianapolis. He also made a small but no less important



Amos William Butler

collection of local mammals. Two mammal finds that he always referred to with special pride were numerous examples of the Lemming Mouse and of the Pigmy Short-Tailed Shrew. At that time both these species were almost unknown, aside from a few scattered specimens.

Among the teachers and friends who influenced Butler in his younger years may be mentioned: J. P. D. John, John M. Coulter, T. A. Wiley, Daniel Kirkwood, Richard Owen, J. M. Wheaton, E. T. Cox, David W. Dennis, J. T. Campbell, Stanley Coulter, Spencer F. Baird, George N. Lawrence, T. M. Brewer, Robert Ridgway, Ruthven Deane, J. A. Allen, Harvey W. Wiley, D. G. Brinton, F. W. Putnam, Otis T. Mason, E. D. Cope, C. V. Riley, C. H. Eigenmann, and B. W. Evermann—all leaders in their respective fields. At Indiana University he came under the inspiring influence of David Starr Jordan. In addition to these personal contacts he carried on an extensive correspondence with American and foreign naturalists. After I became acquainted with Butler, he was one of my best correspondents.

Butler was a born naturalist and loved nature in all its aspects. He was first of all an ornithologist, his earliest papers being devoted to birds, and, strange to say, the first was entitled "Birds Seen in Mexico," because as a youth he had visited that country. He was also interested in the prehistoric remains at San Juan Teotihuacan and published some notes on them. His most important ornithological work, Birds of Indiana, a volume of 673 pages, was published in 1898, in the Twenty-Second Annual Report of the Indiana State Geologist for 1897. Ever since its inception he kept accurate notes on the migration, habits, and records of Indiana birds, always with the thought in mind of bringing out a second edition. It was one of the regrets of his life that he was unable to do so. His last ornithological paper was a short note: Common Tern and Wilson's Phalarope nesting in northern Indiana (Auk **54**:390. 1937). An obituary by T. S. Palmer appears in the same volume, pages 573 and 574.

Next to birds came mammals. He published the first state list in 1894, as well as numerous papers about mammalia in the vicinity of Brookville. He also published other shorter papers on Indiana amphibians and reptiles and a special one on snakes.

Butler was a many-sided man. Although natural history was his chief avocation, as he grew older he turned his thoughts to Man, first to the aborigines, so that he became an archeologist of no mean attainments. Then his attention was directed to the living men about him so that in 1898 he became Secretary of the Indiana Board of State Charities on these two conditions: that politics should not enter into the work of the Board, and that he should have a free hand in the selection and discharge of all employees under him. He held this position with credit to himself and honor to the state for a period of twenty-five years, when he voluntarily retired.

This work led him into the study of penology and reformatories in general. It was his firm belief that quick, certain, short sentences were more effective in preventing crime than long drawn out prosecutions with uncertain convictions. Most of his recommendations were incorporated in Indiana statutes which have served as models for several

other states. It was surprising to talk with Butler, the ornithologist, and find him also an expert on prison conditions in Boston and other cities. It is generally felt that charity appeals more to the emotions than to the reason and that there is little in common between the philanthropist and the scientist; Butler, however, brought to his work as Secretary of the Board of State Charities a trained, scientific mind so that he applied science to his sociological activities in the same way that he applied science to his zoology. He was not only nationally but internationally known for his work on penology.

Butler was a great believer in organized science, holding that those who felt alike should meet often and exchange views. He thus early became associated with the American Association for the Advancement of Science, and in his early years he took an active part in it. He was Secretary of Section H in 1886 and of Section F in 1898, General Secretary in 1892, and Vice-President in 1900. It is sad to realize that he died only a few months before the American Association had a very successful meeting in his home city of Indianapolis. He was chairman of the local committee on arrangements but, on account of ill health, did practically no work.

Likewise he early became an associate member of the American Ornithologists' Union, being advanced a member in 1901. He was ornithologist of the Indiana State Department of Geology and Natural Resources in 1896.

The first record of his participation as organizer of those interested in scientific work dates from 1878 when he was a student at Indiana University and one of the founders of the Owen Scientific Association. In 1881 he was a founder of the Brookville Society of Natural History and in 1882 a charter member of the American Forestry Association. In 1885 he was the chief founder, practically the father, of the Indiana Academy of Science, serving as its secretary for the first eight years of its existence and later becoming president. In 1893 he was chief founder of the Brookville Anthropological Club. In 1898 he was the chief founder of the Indiana Audubon Society, which honored him with a testimonial dinner in 1932. A full account of this dinner and all of the toasts were printed in the *Noblesville Daily Ledger*, volume 45, number 150, June 25, 1932. In 1903 he was a founder of the American Anthropological Society. In 1910 he organized the American Committee on International Prison Congress in Washington. In 1916 he was a founder of the Society of Indiana Pioneers, serving as its president for three years. In 1916 he was a founder of the Indiana Committee on Mental Defectives and in the same year a chief founder of the Indiana Society for Mental Hygiene and afterwards president. In 1919 he was a charter member of the American Society of Mammalogists. He was a member and founder of the International Society of Mental Hygiene and a member of the Sociedad Antonio Alzate of Mexico. He was president of the Indiana State Conference of Charities, 1915, secretary and later president of the American Prison Association, and a member of the U. S. Committee on Observance and Enforcement of Law, 1930-31.

It is beyond mere words to express the character, enthusiasm, and industry of this prominent citizen of Indiana and friend of mankind as

well as of the lowly beasts and birds of the field. He had them all at heart. To know him was to love him. He was a striking and interesting figure at every meeting of the State Academy which he could possibly attend. He regarded it with particular pride and was highly pleased at the celebration of its fiftieth anniversary in Indianapolis in 1935. He stimulated the younger members of the Academy to more and better work. His genial smile and humor will long be remembered by those fortunate enough to have known him. The versatility of his life is shown by a glance at his bibliography. No one would suspect that Butler, the vertebrate zoologist, was Butler, the penologist. He shone alike in both fields. It is given to but few men to be so versatile and to have such wide interests, starting in boyhood as a naturalist, developing in manhood to one interested in the care of prisoners and of the feeble-minded and the distribution of charities, and yet never losing sight of the wonders of nature.

His home life was a happy one. On June 2, 1880, he was married to Mary Reynolds, of Brookville, Indiana, who like himself was a descendant of early pioneer families. The last few years of his life were marked by ill health, but he never swerved from his ideals and his love of Man and Nature. He died August 5, 1937, after a month's illness. Doctor Butler is survived by his widow, four children, Mrs. Shelley Watts, William Reynolds Butler, Gwyn Foster Butler and Mrs. Merritt Harrison, and eight grandchildren.—*Marcus Ward Lyon, Jr.*

The Brookville Society of Natural History was the first evidence of Butler's organizing ability. Later comes the Indiana Academy of Science. I well remember the long months of persistent work he put into it, the innumerable letters he wrote, the all too frequent statements: "Not interested"—"believe such an organization would be both useless and short lived." But he persisted. The Indiana Academy of Science came into being and was kept alive during its earlier years because he refused to allow it to die. It would not have been born, nor would it have lived, without Dr. Butler's genius for organization. . . .

In the first shock of our sorrow at his passing, we are more apt to recall his *personality*, than his work. We think of what he *was* rather than what he did. . . . So to a kindly, genial man, to my warm personal friend for many years, I pay this tribute—but to a *great* man of wide knowledge, of worthy achievements, serving others at sacrifice, I pay *homage.—From a tribute to Dr. Butler, read by Dean Stanley Coulter in the general session of the annual meeting of the Academy, November 5, 1937.*

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In addition to these publications, Dr. Butler prepared the twenty-five Annual Reports of the Board of State Charities of Indiana, for 1898 to 1923, inclusive.

JOHN B. DUTCHER

Decatur, Indiana, July 17, 1875.

Indianapolis, Indiana, July 15, 1937.

Professor John B. Dutcher was born on a farm near Decatur, Indiana, July 17, 1875, and died of a heart attack at the Long Hospital, July 15, 1937, lacking but two days of being 62 years of age. Before entering Indiana University as a student in 1904, he had taught in a a district school and in the Decatur high school and had studied two years at Tri-State College. He received the A.B. degree in Physics from Indiana University in 1906, the A. M., 1907, and the Ph. D. in 1915, having studied one year while Instructor at the University of Pennsylvania. Professor Dutcher's entire career should be a lesson to those who feel that one has to have money or a pull to get anywhere in this life. He was a self-made man, meeting all obstacles and trials with determination to overcome them and succeed. And he did succeed. He succeeded in becoming a physics teacher than whom, in the writer's opinion, the state of Indiana has produced none better. He succeeded in building up courses in mechanics, heat, optics, and modern physics the equal of any, anywhere. In spite of lack of adequate funds, he succeeded in equipping a laboratory in the above subjects, far better than many laboratories equipped from apparatus catalogues. Half the apparatus and equipment of his laboratory was designed by him and made in the Physics Department shop.

The University was not slow in recognizing the peculiar qualities which made Professor Dutcher such a successful teacher. He was made an Instructor in Physics in 1907, Assistant Professor in 1909, Associate Professor in 1915, and Professor in 1922, a position he held until his death fifteen years later.

Professor Dutcher was a Methodist, a Mason, member of the American Physical Society, Sigma Xi, Phi Beta Kappa, the Indiana Physics Teachers' Association, and the Board of Directors of the University Y. M. C. A., and Director and Vice-President of the Workingmen's Federal Savings and Loan Association. He was a Fellow of the Indiana Academy of Science, always attending the meetings and taking an active part in them.

In Dr. Dutcher's death the Indiana Academy loses a faithful and respected member, the University a brilliant, inspiring, and beloved teacher, and the state an honored citizen.—*Arthur L. Foley.*

STACY OTTO HAWKINS

Shelby County, Indiana, September 6, 1899.

Gainesville, Florida, July 10, 1937.

Stacy Otto Hawkins, Assistant Plant Pathologist in the Florida Agricultural Experiment Station, died at Gainesville, Florida, July 10, 1937, after a short illness.

He was born in Shelby County, Indiana, on September 6, 1899. His early education was received in the public schools of his home county. He received from Indiana University the A.B. degree in 1923 and the A.M. in 1926. In the meantime he had taught in Marion College and in the Marion High School, Marion, Indiana.

In 1925 Mr. Hawkins was appointed Field Assistant in the Department of Plant Pathology of the Florida Agricultural Experiment Station and was located at Homestead to study diseases of tomatoes. His work resulted in the development of effective methods of control of the nailhead spot and Phoma rot diseases. In 1931 he was promoted to Assistant Plant Pathologist, and in 1936 he was transferred to Gainesville to work on treatments for the control of seed- and soil-borne diseases.

Mr. Hawkins was a member of the American Phytopathological Society, the Indiana Academy of Science, and the Florida Academy of Science. Papers which bear his name, as author or co-author are: **1925**—Some Xylarias of Indiana. Proc. Indiana Acad. Sci., **34**:225-29. **1932**—Gray leafspot, a new disease of tomatoes. Florida Agr. Exp. Sta. Bull., **249**. **1933**—Some effects of lightning on tomato plants. Proc. Indiana Acad. Sci., **42**:57-59. **1934**—Control of Phoma rot of tomatoes. Florida Agr. Exp. Sta. Press Bull., **467**. **1937**—Experiments for the control of Phoma rot of tomatoes. Florida Agr. Exp. Sta. Bull., **308**. (To be published as Bulletin of the Florida Agricultural Experiment Station.) Tomato diseases in Florida in relation to cultural practices.

RALPH EMORY NELSON

Fowler, Indiana, October 15, 1886.

W. Lafayette, Indiana, July 1, 1937.

The death of Ralph Emory Nelson, Professor of Organic Chemistry at Purdue University, took a loyal and distinguished member from the Indiana Academy of Science on July 1, 1937. The son of Charles and Minnie Hinkle Nelson, he was born on a farm near Fowler, Indiana.

Following the usual preparatory education in his home community, he entered Purdue University in 1907 and was graduated from the School of Science in 1911. His teaching career started that fall in the Department of Chemistry, where he served in different positions from laboratory assistant to chairman of the department. He had only recently resigned the latter position, effective the day before he died. Twice during the twenty-six years his work was interrupted, once in 1916 to secure a Ph.D. degree at the University of Chicago and again in 1918 to serve as first lieutenant in the Chemical Warfare Service in Washington, D. C., in charge of the machine testing of American and German cannisters for gas masks.

Professor Nelson was an active worker in organic chemistry, reports of joint researches with his graduate students appearing frequently in the Journal of the American Chemical Society. His investigations included molecular rearrangements, general synthetic work, particularly with selenium and vanadium, and the utilization of chlorinated hydrocarbons. At the time of his death he had just finished proof-reading a new book, An Outline of Organic Chemistry, written in collaboration with Professors E. F. Degering and J. R. Harrod.

His outstanding contribution to science was his work as a teacher. For two decades it was such that his popularity as an instructor of chemistry has probably not been surpassed at Purdue. Each year he won the admiration and affection of hundreds of students by his sympathetic understanding of people, by his ability to present chemistry interestingly, and by his own example as a man. The basis for this deserved popularity is indicated in the words of a former graduate student: "I have yet to encounter a man having more fine qualities than Dr. Nelson. He was a teacher of rare ability. To appreciate the depth of his knowledge required more than passing acquaintance, for he never attempted a superficial display."

In addition to Professor Nelson's membership in scientific organizations, such as the American Chemical Society, the Indiana Academy of Science, Sigma Xi, and Phi Lambda Upsilon, he was actively affiliated with the Theta Chi Fraternity, the Masons, the Christian Church, the Boy Scouts and the Lions Club. His associates, both in these organizations and in the Purdue Faculty, will treasure a memory of him which has been voiced by one of his fellow-Lions: "He was highly esteemed by the other members for his fine character, even disposition, and balanced judgment. Ever modest and unassuming, tolerant and unprovocative in his opinions, he had no enemies and a wealth of friends."

In the passing of Professor R. E. Nelson hundreds of students have been deprived of a friend, counselor, and worthy example of manhood. Indiana has lost a splendid citizen and Purdue University an outstanding teacher and an alumnus of whom the institution could be proud.

—M. G. Mellen

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WILL SCOTT

Houston, Indiana, April 20, 1877.

Indianapolis, Indiana, October 17, 1937.

The innate fineness of character and simplicity of manner which were typical of Will Scott and which endeared him to all make it difficult to write these words. Dr. Scott's early academic training at Indiana State Teachers College, Terre Haute, qualified him as a high school teacher, and for several years he taught in the New Augusta and Bloomington High Schools. His first association with Indiana University came in 1902 when he enrolled in the summer session at the Biological Station, which he subsequently attended each summer until 1907. He received the A.B. and A.M. degrees in 1908 and the Ph.D. degree in 1911. His first university appointment, as a Fellow in Zoology engaged in a study of cave plankton, was granted in 1907, and from that time until his death he held the following university positions: instructor, 1908-1911; assistant professor, 1911-1919; associate professor, 1919-1921; professor, 1921-1937. He was appointed director of the Biological Station in 1920. He was a member of Phi Beta Kappa, Sigma Xi, American Society of Zoologists, Ecological Society, American Association for the Advancement of Science, and Indiana Academy of Science. He served as president of the last named in 1935.

Dr. Scott's first scientific publication was an "Ecological Study of the Plankton of Shawnee Cave," and his viewpoint in all his succeeding scientific work remained primarily that of an ecologist. The late Dean Eigenmann influenced his early biological training, but Dr. Scott also developed independently a very broad outlook on problems of freshwater biology. Much of his research in later years was devoted to various aspects of lake and river morphometry and sedimentation, as well as more strictly biological phenomena. As director of the Biological Station, Dr. Scott could be in the field during the summer months, and he was also given assistance by the State Department of Conservation, which enabled him on numerous occasions to send students on extensive surveys of the lake and river systems of the state. This study finally was the basis for detailed data on nearly one hundred lakes. At the time of his death he was engaged in a study of fish scales and egg counts in game fishes, in order that age might be correlated with rates of growth and reproduction under various field conditions. According to his own statement, his research interest was twofold: "An analysis of the physical, chemical, and biological conditions in the freshwater habitat,"

and "the various factors which influenced productivity in fresh water." Throughout all his work he was concerned with the practical application of his data, but his scientific philosophy can best be summarized by a statement which he wrote about a year ago: "I have always maintained that the best practical results are those incidental to general studies."

Dr. Scott was quite informal in his teaching and endeavored to reach the superior student rather than the average undergraduate. This, consequently, was an obstacle in some cases for those who were introduced to biology for the first time, but an advanced student found in this informality the stimulus which can result only from a delightful personal contact. Dr. Scott drew his lecture material from his personal experience as well as from a wide knowledge of diverse fields, and the conservative way in which he presented his information remains as an ideal scientific attitude to challenge his colleagues. Will Scott exerted a profound influence upon the development of not only his own students, but also all those who came to know him during their formative years as graduate students. A kindness which dulled the sharp edge of criticism and a willingness to help at any time were characteristics of the man.

A consideration of Dr. Scott's contributions to science and the University precludes any extensive reference of a more personal nature. Suffice it to say, however, that he gave unselfishly of time and energy to his community, and that there are many who feel the loss of his personal friendship more keenly than they do his loss to science. He cared little for personal reward and nothing at all for ostentation, and he leaves to us the memory of excellent scientific achievement which was mellowed by a gracious personality.—*W. R. Breneman.*

PRESIDENTIAL ADDRESS

Science and Modern Thought

WILL E. EDINGTON, DePauw University

Nineteen hundred years ago Jesus of Nazareth stood on trial before Pilate, and, in the course of his questioning of Jesus, Pilate asked, "What is truth?" To the scientist no more profound question could be asked unless it is "What is reality?" Earlier in his ministry Jesus had said: "Ye shall know the truth and the truth shall make you free." Every scientist realizes the truth of this statement for men have been freed from the handicaps of space and time and from the perils of many diseases through the truths acquired by scientists from their experiments and controlled observations.

This has been called a scientific age, and the man in the street has become so accustomed to hearing of new discoveries that he receives them and accepts them as matter of course, without giving much thought or having much concern as to the ultimate consequences of such discoveries. His thinking is unconsciously colored and influenced by these discoveries, most of which he does not understand or ever expect to understand. He reasons that they must be good for they bring him physical comfort, relieve his physical burdens, free him from many fears of disease and poverty, furnish him many foods and luxuries denied his forefathers, make available to him many pleasures, and, in general, give him on this earth what kings were denied in past centuries and what would have exceeded the prayers of and seemed heavenly to the suffering masses. At times he has had misgivings as to whether it could continue, and he has feared that too rapid advancement of scientific knowledge and invention might cause him trouble, but, with one development following another, his misgivings and fears have disappeared as new blessings are showered upon him. Many of his superstitions have passed away and he has learned to look upon many phenomena not understood by him, with curiosity rather than fear. He has developed a rather thoughtless and blind faith that science will eventually solve all his health, food, transportation, fuel, and sundry other problems involving his physical well being. In his daily newspapers and current popular magazines, some scientific, he reads of geological, paleontological, archeological, chemical, astronomical, and physical discoveries which involve tremendous stretches of time and space, and, not being discriminative, he accepts these statements as facts; for do they not come from the same general source that has provided him with other discoveries which he has found good? Does the same fountain give forth both sweet water and bitter?

Science has taught that all the phenomena of nature are manifestations of definite laws, which, if not already known, are capable of being known by man. Moreover, science further teaches that if the laws governing certain phenomena are known, these laws may either be made

available for man's use, or man may adjust himself to them for his own welfare. Science teaches that nature is orderly, and anything that appears capricious or supernatural or contrary to known laws is due to ignorance of the laws governing such phenomena rather than the suspension of known laws. In other words the scientific attitude toward phenomena is one of curiosity, inquiry and hope for understanding and solution rather than one of fear and fatalism and all that goes with hopeless ignorance. Also the scientific attitude demands that scientific conclusions be based on experimental evidence and be subject to constant checking by further controlled experimental investigation.

It has not always been this way. There was a time when mere authority dominated beliefs, and to question this authority was to risk exile, prison, and even death. After the Greeks there was little scientific progress for many centuries. The church based what little that passed as science on the authority of Aristotle and on pure reason, and they built up the theological and philosophical doctrines through logic and speculative thinking, which, when applied to physical phenomena, have often brought the church into conflict with the conclusions derived from experimental investigation of these phenomena. Roger Bacon, an English Franciscan monk, who lived in the thirteenth century, was probably the first, after the Greeks, to insist that physical science be based on experiment, as Aristotle had taught that it should, rather than on arguments "deduced from premises resting on authority." Bacon held mathematics to be the basis of all sciences. He was deeply influenced by the works of the twelfth century Arabic philosopher, Averroes, whose commentaries on Aristotle had been translated into the Latin. However, Bacon was too advanced for his age, and although the works of Averroes continued to influence the thought of the Christian schoolmen, three centuries elapsed before Vesalius, Frabricius, Galileo, Gilbert, Brahe, Palissy, Harvey, and Francis Bacon appeared on the scene. All these men except Bacon were primarily experimenters; Bacon was a philosopher. Modern science may be said to have really begun with these men.

The sixteenth century had seen the quickening of mathematics which prepared the way for the marvelous developments of the seventeenth and eighteenth centuries. The theory of Copernicus, put forth simply as an hypothesis, that the earth rotates on its axis and revolves around the sun in a closed orbit, followed by the astronomical observations of Tycho Brahe, and the enunciation of the planetary laws by Kepler, were simply consistent with the spirit of the times, which had led to the discovery of America by Columbus, the experimental proof of the rotundity of the earth by Magellan, and the invention of the telescope with its subsequent verification of the Copernican theory, which dealt death blows to the Ptolemaic theory of the universe and the theological doctrines built on such authority.

Up until the sixteenth century what little that passed as science was based on the Aristotelian method of reasoning by the deductive method, that is, reasoning syllogistically from general principles. Francis Bacon, influenced by the works of Gilbert and probably Palissy, insisted that the scientific method should be one where facts must be collected

and investigated, that nothing should be taken for granted, but that general truths should be derived from these facts and then tested and verified by further experiment. Bacon's method is the inductive method, first definitely stated by Palissy, and all that Bacon lacked of giving what is now accepted as the scientific method was the recognition of the value of hypotheses.

The seventeenth century is remarkable for the fundamental nature of its discoveries and their influence today. Galileo established the first law of motion, determined the laws of falling bodies, and possessed clear notions of acceleration and the independence of different motions. He understood centrifugal forces and gave a correct definition of momentum. Galileo is considered as the founder of dynamics. Huygens invented the pendulum clock, improved the telescope, discovered the true nature of the rings around Saturn, stated the laws of centrifugal forces, and was the first to write a formal treatise on probability. Huygens also was author of the theory of light as due to vibrations in the ether which filled all space. Fermat and Pascal also made contributions to the theory of probability, and Halley published a mortality table and applied some of the ideas of probability in an attempt to ascertain the prices of annuities on lives. Römer, through a study of the eclipses of Jupiter's moons, discovered the finiteness of the speed of light. Newton, familiar with the works of Kepler, Galileo, and Huygens, enunciated the law of universal gravitation and the three laws of motion. He explained the decomposition of light and the nature of the rainbow, formulated some of the laws of optics, invented the reflecting telescope, and was the author of the corpuscular theory of light. Newton's law of universal gravitation is expressed in terms of mass, distance, and time, where time is included in the conception of force.

Also the seventeenth century saw the development of Descartes' philosophy which is still important today. Descartes, celebrated as a mathematician and philosopher, with his subjective method starting with, "I think; therefore I am," as his first scientific truth and major premise, upon which all other scientific truth must be based, approved of Bacon's methods in natural science and hoped through the dissection of the brains of animals to find something about the psychic processes. Spinoza, Leibnitz, Hobbes, Locke, and Berkeley, through intuition and speculative thinking, expressed many ideas that will be found to have much in common with modern thought.

The eighteenth century is very important in mathematical history on account of the great progress made in mathematical discoveries and their application to physical phenomena. Also the work of the great mathematical thinkers of the eighteenth century prepared the way for one of the profound developments in mathematical interpretation that came to fruition in the first half of the nineteenth century and revolutionized mathematical thinking. Euclid, who lived about 300 B. C., compiled all the geometry known to the Greeks at his time. This is the geometry taught in our high schools. Among the postulates or axioms used by Euclid was one known as the Fifth or Parallel Postulate. The history of this parallel postulate, or axiom, is very interesting for, since the time of Euclid, various mathematicians at various times had

questioned it as an axiom. Many attempts were made to prove it, and then finally two mathematicians, Lobatschewsky and Bolyai, working independently, came to the conclusion that it was not provable simply because it was a definition instead of an axiom. Accordingly, they constructed a logical, consistent geometry and trigonometry by defining parallel lines independently of Euclid's Postulate. In their geometry, sometimes called hyperbolic geometry, the sum of the three angles of a triangle is always less than two right angles. This geometry, based on intuition, as is Euclid's, was the first geometry constructed that did not rely on physical experience or observation for its acceptance. In fact, it seems to contradict experience. Its discovery marked an epoch in mathematical thinking. The discovery of this geometry was followed by the discovery of what is known as elliptic geometry by Riemann in which the sum of the three angles of a triangle is always greater than two right angles and the straight line is not infinite in length. This is the elliptic or Riemannian geometry, which has served as the basis of representation for the physical space required by the theory of relativity. The well known Euclidean geometry is a limiting case of both the hyperbolic and elliptic geometries. Since the discoveries of these two non-Euclidean geometries, many other geometries have been discovered, as abstractions at least, which are logical and consistent. As a result of these discoveries, the foundations of mathematics have been subjected to severe and critical investigation.

Naturally the question to be asked is: which is the true geometry? Mathematically they are all true since truth here means merely consistency. The question of truth in fact is replaced by one of reality as based on our sense experiences in the physical world. The answer at present is that, for practical purposes on this earth, the Euclidean geometry is sufficiently accurate, but for astronomical space the geometry must be elliptic. However, the chief importance of the discovery of non-Euclidean geometry does not lie in its apparent explanation of some of the phenomena of nature, but first in the fact that the application of mathematics to a phenomenon does not mean that the conclusions derived must be true or real; second, the reality or truth of the conclusions must be based on experimental evidence; and, third, great care and caution must be exercised in setting up axioms, definitions, and hypotheses in the explanation of physical phenomena. As is to be expected, the philosophers became interested in mathematics.

Mathematical reasoning is primarily deductive; that is, certain statements are accepted as basic and then conclusions are deduced from them. These basic statements may be the result of intuition or inductive reasoning or merely pure assumption. First, certain notions or concepts are taken as undefined. For example, in the ordinary Euclidean geometry, the concepts *line* and *point* are taken as undefined. Then a set of relations, called axioms, are set up and certain definitions may be given in terms of the undefined elements and axioms. Thus, "The straight line is the shortest distance between two points," is taken as an axiom and from this axiom and the undefined elements, the definition of the circle is given. Then certain conclusions, known as theorems, are deduced by correct reasoning from the set of undefined terms, axioms, and

definitions. The whole body of undefined terms, axioms, definitions, and conclusions or theorems is said to constitute a mathematical or logical system. The check on this system is its consistency, and the question of its truth or falsity is meaningless. The axioms, of course, must be consistent, and in order to reduce their number to a minimum, the attempt is made to choose axioms that are independent of each other, that is, no axiom may be deduced from any one or more of the other axioms. The discovery of conclusions or theorems may occur as the result of inductive or deductive reasoning, reasoning by analogy, intuition, observation, statistical analysis, *et cetera*, but the proof of the conclusions, as was said before, must be established deductively.

Pure mathematics deals with abstract mathematical systems. It may happen, however, that the undefined terms, axioms and definitions, may be given physical interpretations, or certain physical assumptions may be appended to the abstract mathematical system, with the result that we have applied mathematics. Then the conclusions will be valid only provided they check with experimental results. Since the principal business of all science is to measure and to weigh, it follows naturally that mathematical methods will find application in all the sciences, and all sciences dealing with quantitative data must become mathematical in their methods and reasoning. Hence we should not be surprised to find, not only the astronomers, physicists, and chemists thinking and speaking in mathematical language, but also the biologists, psychologists, economists, and others.

The great advantage to be derived from stating a theory in mathematical language or terms lies in the possibility of making predictions, which suggest further experimental work. Thus the mathematical work of Maxwell in 1865 led him to predict that light is an electro-magnetic phenomenon and that an electric discharge must create disturbances in the ether which travel through space with the speed of light. This was verified by Hertz in 1888, and these experiments led to the modern radio. The discoveries of the planets Neptune and Pluto are two other excellent illustrations of the power of mathematical prediction. The prediction of eclipses, by means of mathematical computation, is, of course, a common affair in astronomy.

Now the seeming absolute reliability of such laws as the laws of motion and the law of universal gravitation, which are expressible in mathematical language and which have led to new discoveries and have made predictions possible that have been consistently verified, naturally leads one to believe in complete dependence on results yet to be discovered or verified. This belief in one's ability to predict and forecast on the basis of supposed known laws is a sort of scientific extrapolation and leads to a deterministic philosophy toward the physical world, sometimes called the certainty principle. Out of it came the mechanistic ideas so prevalent at the close of the last century. In other words, if this idea is carried to the limit, one has scientific predestination.

The nineteenth century was rich in ideas which have had a tremendous influence on philosophical thought. Following the mathematical discoveries already discussed, came the principle of the conservation of energy, the principle of least action, the second law of thermo-dynamics,

the kinetic theory of gases, the theory of evolution, the germ theory of disease, Mendel's Laws, and others.

The principle of the conservation of energy was supposedly firmly established through the work of Robert Mayer, Colding, Joule, and Helmholz. The idea was not new, for there are evidences of it in the works of ancient philosophers, and Descartes held that it was self-evident, but it required Joule's discovery of the mechanical equivalent of heat and careful verifications of chemical changes, *et cetera*, all done experimentally, to place it in the same category as the law of universal gravitation.

The second law of thermodynamics simply states that the amount of available energy in the universe is decreasing. As an ultimate consequence, if this law is true, the physical universe will eventually become a cold, static, lifeless system. Naturally any philosophy built on such a law will be pessimistic. Here is an expression of the certainty principle with its mechanistic and predestined conclusions which has brought about such a book as *The Degradation of the Democratic Dogma*, by Henry Adams.

The kinetic theory of gases, based on the molecular structure of matter, was formulated mathematically by Clausius, Maxwell, and Boltzmann. It states that the temperature of the gas is merely a manifestation of the average kinetic energy of agitation of the gas particles, and the pressure on the wall of the container of the gas is due to the "sum total of the innumerable impacts which the particles individually make upon it, and is measured by the total change in momentum imparted every second to the walls." The kinetic theory is a macroscopic study of the results of the movements of the gas particles and is based on the idea of probability. Thus, no attempt is made to record the history of any one particle nor to predict what any one particle may do, but only the composite effect is forecast. An analogous method of reasoning is used by a life insurance company. Mob psychology is based on similar reasoning. The concept of probability is fundamental in modern thinking. It enters all kinds of scientific thinking. For example, in genetics it is possible for a mulatto couple to produce a white child without a single Negro gene or a Negro child without a single White gene, but the probability is small. Nevertheless it exists and consequently the concept of race mixture is quite different from the mere mixture of blood.

The controversies that have arisen over the theory of evolution are well known. Many of these were due to misconceptions. Now the theory of evolution deals with that part of nature which involves living matter, whereas the physical laws just discussed are primarily concerned with inanimate or mechanical systems. Accordingly, the theory of evolution immediately came into conflict with certain notions or dogmas of the church, particularly as the theory of evolution applied to man. The idea of a slow orderly change was accepted in astronomy and geology long before it was accepted in biology as based on research. The idea of evolution can be traced back to Aristotle and other Greek philosophers. "Scientifically, evolution is a law of nature and is proved or established as firmly as is the law of gravitation, and precisely in

the same way. Just as the theory of gravitation was an inference derived from facts and has served to explain and rationalize other facts, so the theory of evolution was offered as an explanation of facts and has served to make intelligible enormous numbers of facts obscure on any other grounds."[1] Looked at in an unbiased and dispassionate way, the theory of evolution is merely an attempt to explain the methods used by the Creator in bringing about the 800,000 different species of animals and the 300,000 species of plants already known and described in biology. It states that the physical manifestations of life are not static, and its principles, supplemented by the practical applications of Mendel's Laws and genetics, as applied in modern agriculture, animal and plant breeding, *et cetera*, have changed and are now changing modern thought. It influences our thinking and actions in ways which we accept unconsciously, as, for instance, that no two individuals are identical physically, which serves as the basis of identification by finger prints.

The germ theory of disease, based on the work of Jenner, Pasteur, and Lister, has had as profound but more subtle influence on thought as has the theory of evolution. Since it directly concerned the welfare of mankind it also came into conflict with dogma, scientific or otherwise, and, while it is not yet generally accepted and probably never will be, nevertheless, its effect on human thinking has been sufficient to remove visitation of disease from the realm of the supernatural. An epidemic of typhoid fever or smallpox is no longer ascribed by thinking people to the wrath of a vengeful God, to be submitted to with resignation and despair or accepted as blind fate or predestination. Fortunately or unfortunately the fear of disease does not have the same power nor the same kind of power that it once had to control man's moral and spiritual actions.

As a result of the scientific developments of the nineteenth century there grew up among scientists a feeling that all the phenomena of nature might be explained on the basis of motion of the particles or atoms of the bodies concerned. As long as this conception was limited to inorganic matter it was of interest to the scientists only, but when it was made a working hypothesis in biology by considering life itself "an expression of the transformations of energy and of matter in a large group of materials, differing in detail, but alike in certain fundamental respects—materials known technically as protoplasmic and which constitute what Huxley termed 'the physical basis of life,' "[2] it came into conflict with the vitalistic conception that life involves in part at least manifestation of laws and forces not to be found in the inorganic world. While at one time the question of the mechanistic conception versus the vitalistic conception produced more heat than light because of the dogmatic attitudes assumed by those taking sides in the controversy, the present attitude is one of uncertainty. However, the discovery of the genes as controlling the heredity of physical characteristics and possibly mental characteristics, the discovery of the organizer center of the embryo which seems to control the differential growth of the embryo, and the discoveries of the chemicals known as hormones which

[1] The Nature of the World and Man, H. H. Newman, Editor, p. 193.
[2] The Nature of the World and of Man, H. H. Newman, Editor, p. 165.

play such a fundamental part in the bodily growth and functions, both mental and physical, tend to support the mechanistic conception; but until life is actually produced by purely physical and chemical conditions, the question must remain open. Nevertheless, these mechanistic discoveries have influenced and will continue to influence modern thought in its consideration of many social problems, such as involve behavior, individual responsibility, freedom of the will, *et cetera.*

The present century has been very productive of scientific discoveries and theories that are moulding thought. The theory of relativity, the quantum theory, the theory of an expanding universe, the discovery of cosmic rays, the discovery of radium and radioactivity, and the discoveries in subatomic physics are too recent to determine just what the ultimate effect on philosophic thought will be. Of one thing we can be certain and that is their scientific discussion must be confined to the very few who have the mathematical training to interpret the mathematical symbolism which serves as the means of their expression. In other words, the deductions from the theories may be made by only a few, and their conclusions must be accepted or rejected by the great majority in exactly the same way that religious dogmas are accepted or rejected. There is this one difference, however, namely, that any one with the proper skill and resources at his command is free to verify the experimental results and thus check the conclusions.

The theory of relativity grew out of the famous Michelson and Morley experiment, first performed in 1887, in an attempt to detect the earth's motion relative to a supposedly stationary luminiferous ether, the expectation being that the speed of light would be slightly different when measured along and at right angles to the earth's orbital motion. No such difference was detected, and the only possible explanation was that the measuring apparatus became shorter when placed in line with the earth's orbital motion than when it was placed at right angles to the orbital motion. The idea that space was filled with this ether came about through the acceptance of light as a wave phenomenon which seemed to require some medium for the propagation of the waves. Newton, who believed light to be corpuscular, considered space to be empty. The theory of relativity rejects the idea of a stationary ether and makes assumptions whereby the ether medium is not necessary. The special relativity theory makes two fundamental assumptions, first, that there is nothing definite out in space like an ether or a fixed condition whereby absolute motion may be detected, and, second, that the speed of light is independent of the motion of the light source, that is, the speed of light is the same to all observers regardless of their motion or any motion of the light source. There are, of course, other assumptions which bring about a conception of space and time that is different from the Newtonian conception. "It appears that the universe is four dimensional, its dimensions being length, breadth, thickness, and *time;* and this 'space-time' is curved in a fifth dimension, the curvature being the greatest in the neighborhood of bodies of greatest mass."[3] Since the results differ from the Newtonian theory only when the speeds are very great or the masses are enormous, the theory of relativity finds its verifications in the

[3] Astronomy, Third Edition, J. C. Duncan, p. 329.

study of the masses of the stars, the motions of the planets, the motions of atoms and electrons, particularly in the spectrum studies of the elements, and the phenomena of light. It affords a much simpler explanation of the laws of the physical universe by establishing fundamental relations between mass and energy, electricity, gravity, and radiation in general. It is this unification or integration, which is accomplished through the relativity theory, that is important and which is influencing modern thinking.

Closely allied to the theory of relativity is the quantum theory. This grew out of a study of radiation from the heated ideal black body. Also, in what is known as the photoelectric effect, electrons are liberated from a metal surface upon which light is falling. The remarkable fact about this liberation is that, while the total number of electrons liberated is proportional to the intensity of the light, the energies of the emitted electrons are independent of the intensity. This fact leads to the conclusion that the atom is capable of existing only in certain definite stationary states, each state having a certain definite energy. Since the change in state results in radiation and light is a form of radiation, another conclusion is that light is corpuscular in its structure, which is similar to Newton's idea. But light obeys also the wave theory and the attempt to explain interference and diffraction by means of the corpuscular theory alone has not been satisfactory. Thus a seeming contradiction exists. The most recent theory reconciles the two theories by assuming "that atoms emit wave fields as in the electromagnetic theory, emitted by certain oscillators connected with the atom, and vibrating with the emitted frequencies. These waves do not carry energy, but serve merely to determine the probable motion of the photons. The rate of emission of waves by the oscillator determines the probability of emission of photons."[4] The relations between the photons and waves are statistical, and a similar relation exists between electrons and waves. Based on experimental results the theory is extended to mechanics and leads to what is called statistical mechanics or wave mechanics of which the Newtonian mechanics is a limiting case.

As you may have observed, the ideas of probability are fundamental in the quantum theory. Probability is a means of securing macroscopic results as against microscopic results. Where probability is applied, it is assumed that knowledge of the actions of any one individual may not be predicted with certainty, in fact may not be determinate. Moreover, any attempt to observe the individual may disturb the normal condition, for all we may know, and the results may be different from those that would occur had there been no disturbance. This reasoning leads to the uncertainty principle, now generally accepted in modern physics, and its application is being extended to biology and psychology. This principle of uncertainty strikes at the root of mechanistic determination or scientific predestination. In other words, philosophically, the question of free will enters, and physics is becoming somewhat metaphysical in its interpretations. Modern relativity and the quantum theory are highly mathematical and deal with abstract symbolism that often is impossible of physical interpretation in terms of sense pictures. For their validity

[4] Introduction to Theoretical Physics, Slater and Frank, p. 332.

they must rely on the physical verification of their predictions and not on any possibility, at least at present, of simple pictures of the phenomena which they attempt to explain.

Modern science is dealing with the macroscopic effects of the unseen. The electron, atom, molecule, gene are all invisible. Many laws that seem to be valid are macroscopic laws; that is, they are conclusions based on high probability. Some of these laws do not hold in atomic or subatomic processes. The scientist Dirac has recently stated that, on the basis of certain experimental results, the principle of the conservation of energy does not hold in atomic processes. In like manner, the question as to whether the second law of thermodynamics holds has been raised. The studies in cosmic rays have suggested that the second law of thermodynamics represents only one aspect of the transformation of energy in that the existence of radiant energy in space, both inaccessible and invisible, is ignored. Thus we find modern physics faced with uncertainty in the universality of its important laws.

During the past twenty years, owing to the remarkable discoveries in astronomy, science has become popularized. Eddington, Jeans, Slosson, and others have written for the masses. In fact the public interest in science is so great that the recent book by Hogben, entitled *Mathematics for the Million*, has been among the six best sellers in nonfiction during the past few months. President Roosevelt's birthday balls, the 200-inch telescope, the planetariums, the scientific rearing of the Dionne quintet, the great atom smashing machines, the stratosphere explorations, and numerous other scientific studies hold the interest of the general public. Almost any form of scientific speculation built around a few experimental facts, when told in an interesting way, arouses public interest and too often is accepted by the public as proved conclusions. There is, accordingly, danger that modern thinking will become extremely superficial unless scientists are careful to state what is fact and what is speculation.

Modern science has become what it is through co-operative and group effort. It knows no national boundaries, and practically all nations, without regard for race or color, have made contributions. National self sufficiency is no longer possible, and, once this has become generally recognized, co-operative effort on the part of nations should follow.

Science has led to intense specialization with its attendant narrowness. Also this implies absolute honesty and good faith on the part of the research scientist, for his fellow men must accept his findings without the means of checking them. Modern thinking demands faith, a faith as great if not greater than that required to believe the miracles of the Bible. To accept the picture of the atom with its high speed electrons spinning around a nucleus with space relations similar to the space conditions for the sun and its planets, the whole atom invisible and infinitessimally small, requires faith. To believe that invisible genes, estimated to be one two millionth of an inch in length in the Drosophila, for example, contain the whole mechanism of heredity, and in a physical sense, at least, immortality, requires faith on the part of one not a specialist in biology. This faith to be sure is not the same as blind faith for the observations upon which it is based are subject to check.

The greatest contribution of science to modern thought is the idea of unity in nature. Thus all living creatures are unified through the theory of evolution. All the chemical elements may be built up from electrons and protons, and the disintegration of the atom is an experimental fact. Matter and energy are two aspects of the same phenomenon. Radiation theory unifies the phenomena of light, electricity, heat, cosmic rays, X-rays, *et cetera*. Astronomy has unified the physical universe. Moreover all the sciences are becoming united through the bond of mathematics, and, as they become more mathematical, they become more abstract and are subject to conditions which mathematics imposes. The application of the laws of probability to both physical and natural science tends to unify these fields.

Finally, what is the relation of science to man? Science has been held responsible by some for the cruelty and bitterness that is now in the world, but science should not be blamed for man's misuse of scientific discoveries. Undoubtedly, man considered as an object among objects has little significance, in the light of the discoveries of galaxies and supergalaxies. Science has undoubtedly undermined such beliefs as the suspension of laws in the physical world. Man, reasoning about the immense stretches of space and time which science demands, questions the validity and reasonableness of threats of eternal punishments for moral failures. Moreover science shows that moral delinquency may be often due to functional disturbances in hormone secretions. These facts may in part also account for the apparent decline in interest in personal salvation and personal immortality. However, the failure of man to maintain moral control of himself cannot be chargeable to science. Morality and the things of the spirit are not, at present, at least, the province of science. But we must face facts, and it would be well for the scientists, philosophers, and theologians all to follow the Apostle Paul's advice to the Thessalonians: "Prove all things; hold fast that which is good." Possibly the scientific method points the way for a more demonstrable religion. Science deals with things that can be weighed and measured. There are other things, many of us believe, that cannot be weighed and measured. Science, philosophy, and religion must work together, each recognizing the strength and limitations of the other, each recognized as a manifestation of the Supreme Creator. Both the scientist and the man of religion must realize that ultimately "truth will prevail and error will be confounded, whether it comes from conviction or observation."[5]

[5] Discovery or the Spirit and Service of Science, R. A. Gregory, p. 53.

PROGRAM OF THE SECTION ON ARCHEOLOGY

Chairman: GLENN A. BLACK, Indianapolis

1. Direction of linguistic change. C. F. Voegelin, DePauw University.
2. The homeland of Indian corn. Paul Weatherwax, Indiana University.
3. Concerning migration paths. Paul W. Weer, Indiana Historical Society.
4. Tentative outline of the prehistory of Indiana. Eli Lilly, Indianapolis.
5. The Goodall Focus of Elemental Hopewellian in Indiana and Michigan. Glenn A. Black, Indiana Historical Society.
6. Who built the Mounds? Erminie W. Voegelin, Greencastle.

The title of paper No. 6 was received too late to be included in the program published previous to the meeting. All the above papers were read although two authors were not able to be present.

No abstract of Mr. Lilly's paper is given here because the paper is included as a part of his book, *Prehistoric Antiquities of Indiana,* published by the Indiana Historical Society, 1938.

In keeping with a custom established some years ago, the Archeological Section of the Indiana Historical Society brought an outstate speaker to Indianapolis for the principal address before the Section during the Annual History Conference, December 11, 1937. The speaker chosen was Dr. Florence Hawley Senter of the University of Chicago whose subject was "Dendrochronology."

In view of the widespread interest in this subject it seemed desirable that members of the Academy be permitted to share in this presentation. Notices were mailed to all Academy members, and it is a matter of regret that more did not avail themselves of the opportunity. Dr. Senter, by field and laboratory work, is attempting to do for the upper Mississippi Valley what she and Douglass have done for the southwest, namely, to give prehistoric habitation and mound sites exact dates by the tree-ring method of dating.

Mr. Black was re-elected chairman of the section for 1938.

ABSTRACTS

The homeland of Indian corn. PAUL WEATHERWAX, Indiana University.—The American origin of Indian corn is admitted by practically all authorities. The intensiveness of cultivation and degree of variation indicate two possible centers of origin, one in Peru and the other in Mexico and Central America. The botanical evidences favor the latter, because teosinte, the nearest relative, is limited to this region, and Tripsacum, a more distant relative, has its main distribution in North America.

The Goodall Focus of Elemental Hopewellian in Indiana and Michigan. GLENN A. BLACK, Indiana Historical Society.—During the field season of 1937, an opportunity was afforded for the study of material removed from mounds in the Kankakee-St. Joseph River drainage years ago by interested non-professionals. Meager reports on these excavations had indicated the presence in this area of a rather frequent manifestation of the Hopewellian mound-culture complex.

Material in several museums and private collections was studied and allocated to the mounds of the area by means of a peculiar form of lettering used in numbering the specimens by the individual who conducted the bulk of the explorations. No catalogue has been found which would explain in detail the significance of the numbering system. The area covered by this material includes Laporte and St. Joseph Counties in Indiana and a number of counties in Michigan. The date of specimen recovery goes back to the early eighties.

The best known group of mounds in the region is the Goodall Group located southeast of Laporte in Laporte County. This has given name to the archeological manifestation including all of the components (sites) in the above named area, which combine to form a focus of the Elemental Hopewellian Aspect.

The culture complex is interesting in that it consists not only of determinant traits for the Elemental Aspect of the Hopewellian Phase. In addition there are certain link traits exhibited in the ceramic complex which seem to connect this Focus with some Aspect of the Mississippi Culture Pattern.

In view of the rather complex culture manifestation, it is a matter of extreme regret that such early workers left no field notes indicating the exact relationship, *in situ*, of anomalous forms, burial types, earth strata, and other technical data so important to the modern archeologist.

Direction of Linguistic Change

C. F. Voegelin, DePauw University

Summary: Most linguistic change is in one direction, diversification from a prototype; the LeBoulanger and Dunn manuscripts provide material for suspecting a secondary change in the opposite direction, a merging of two dialects, Peoria with Miami. But Peoria is not supplanted by Miami, for some dialectic pecularities are retained.

One speaks of a relationship between languages, in a descriptive sense, when differences between the languages compared are not haphazard but, rather, follow a regular point-for-point pattern of difference. Thus a *bh–* sound in a Sanskrit word will correspond to a plain *b–* in English, to an *f–* in Latin *(bhratar–*, brother *frater)*, and so on in all the related languages.

From a dynamic point of view, however, languages are regarded as related because they have a single parent, a language no longer spoken naturally; the prototype of the three sounds of the word given above in three languages *(bh–, b–, f–)* happens to be identical with the sound in the first mentioned daughter language *(bh–)*, but occasionally the prototype is not identically preserved in any of the daughter languages. Thus Indo-European $g^{w}h$– never appeared as such, but changed to Greek Φ or Θ or X, and to Latin *f–* or *v–* or *gu–* or *g–* (depending on position in the word and neighboring vowels), not to mention other changes in English and the remaining daughter languages.

Linguistic change, unless otherwise defined, would indicate a change in a direction away from the parent language. Sapir's fertile concept of "drift" limits change to a particular direction rather than permitting random change in many directions; at most, the various branches of the daughter languages can express their willingness or conservatism in following the general "drift."

The sounds of Proto-Algonkin have been changed so as to be almost unrecognizable in the daughter languages, Cheyenne and Arapaho, whereas in two other Algonkin branches of the family, Blackfoot and Eastern Algonkin, the sounds of the parent language have been only moderately changed.

One sub-branch of the Eastern Algonkin branch was represented in the 18th century by at least two dialects, Peoria and Miami. In order to make the successive Algonkin diversifications clear, let us say that 18th century Peoria and Miami diversified from a single parent language, which we may call Primitive P-M; let us say the Primitive P-M, together with other Algonkin languages, must have diversified from an even earlier parent language, Primitive Eastern Algonkin, while this last together with Primitive Cheyenne-Arapaho may have diversified from a still earlier language, Proto-Algonkin. To return to 18th century Peoria and Miami, we should expect to find today all the differences recorded two centuries ago, and, given more time in the future and isolation of groups, we might expect local bands of Miami to father new Miami dialects and local bands of Peoria to father new Peoria dialects.

Our expectations are not fulfilled. Peoria and Miami are not even as distinct as they were two centuries ago (the intervening period doubtless presented far from ideal conditions for dialectic differentiation).

In one of the several manuscripts given by the Jacob P. Dunn family to the Indiana Historical Society, Dunn compares Gatschet's Peoria (recorded in Oklahoma) with Godfroy's Miami (recorded in Indiana) and finds that recent speakers of these languages showed numerous dialectic differences so far as words and meanings are concerned; no sound correspondences show any significant differences. Dunn feared Gatschet had mistakenly taken a Miami informant to be a speaker of the Peoria dialect. In order to test the correctness of his own impressions, Dunn visited Oklahoma, but failed to find really satisfactory informants for the scientific discussion which he contemplated (none of his informants spoke Peoria from childhood on). We have for modern Peoria, then, no other evidence than that presented by Gatschet and, for modern Miami, Dunn's material.

A comparison of a few hundred words shows instances of Peoria and Miami words which are not cognate but which have identical meanings (e. g., Peoria *metcikiletakuka*, Miami *toondwa*, both meaning "bullfrog"), on the one hand, and on the other instances of words having identical form in both Peoria and Miami, but specialized meanings (e.g.: *Nila menätowa* means in Peoria "I bewitch somebody," but in Miami "I am the devil." So also *älikwa* is "grub-worm" in Peoria, but "ant" in Miami.) Far from modern Miami supplanting modern Peoria, the lexical differences are so numerous that we must suppose the speakers had some difficulty in understanding each other completely.

Old Miami, that is Miami as spoken about the 18th century, does not differ from modern Miami, as may be seen from the word comparisons which Dunn has made of older Miami manuscripts and his modern Miami.

Old Peoria, as recorded by LeBoulanger in the early 18th century, shows numerous phonological differences when compared to Miami, whereas the only differences between modern Peoria (Gatschet) and modern Miami (Dunn) are lexical.

Examples of words from the LeBoulanger manuscript are given with Miami cognates in Appendix A in a recent paper in the Prehistory Research Series of the Indiana Historical Society.[1] I may summarize here the phonological differences which distinguish old Peoria from Miami:

(1.) P. *–w–* may correspond to M. *–y–*.

(2.) Various vocalic correspondences are encountered which are difficult to value.

(3.) P. *–r–* generally corresponds to M. *–l–*.

(4.) P. *–r–* also corresponds to some M. *–n–*.

(5.) Most Miami stems beginning in a stop or affricate, at least, have an homorganic nasal consonant before the stop when the first person pronoun *ni–* is prefixed; Peoria employs such a nasal in somewhat less than half of the examples compared.

(6.) Peoria words may end in consonants, while Miami words always end in vowels.

[1]Voegelin, C. F., 1938. Shawnee stems and the Jacob P. Dunn Miami dictionary. Part I, Stems in *p* —. Prehistory Research Series, Indiana Hist. Soc. 1:16-108.

Concerning Migration Paths, or What Became of the Hopewellians?

Paul Weer, Indianapolis

Archeological research in Indiana has discovered within our state manifestations of three basic culture patterns—the Mississippi, the Woodland, and an Unknown, or, rather, phases of this designated as an Unknown pattern. This differentiation is founded on the archeological culture classification plan for the eastern United States, originally proposed by McKern (1). In Indiana, as also in several surrounding states, the problem of distinguishing between the Mississippi and the Woodland patterns, and the differentiation of these from the Hopewellian phase of the as yet Unknown, (or, shall we say; unnamed) pattern, is a peculiarly difficult one because of the apparent diffusion of similar culture traits into the body of the three patterns.

Wissler has suggested that migrations move forward—that the diffusion of traits spreads (2, p. xvi). Diffusion implies migration of ideas from mind to mind and group to group. This is quite a different thing from tribal and group migrations. The proximity of receptive minds is essential to the diffusion of ideas that translate themselves into culture forms; and the migration of peoples is but one method of bringing these minds together. The distinction between migration and diffusion has long been recognized in the Old World; and some of the difficulties attendant upon New World archeological and ethnological interpretations can be traced to the "slowness to recognize that diffusion and tribal migration are different things." (2, p. 183.) Migration is one of the natural avenues of social development. For primitive peoples, migration was set in motion primarily by the pressure of population on food supply; under the banner of conquest it has made the grand epochs of history; as a colonizing force it has transformed the world; and as an agency of free initiative it is one of the most powerful factors in social adjustment. Diffusion enjoys its greatest opportunities among relatively stable populations when they have reached the stage of social and commercial interchange with neighbors and with visitors from afar.

The mingling of culture traits in Mississippi, Woodland, and Hopewellian would imply diffusion among these groups in Indiana. Stratigrahpic differentiation of these traits on suggestive time horizons between them would suggest successive migrations into Indiana of the possessors of these cultures. In prehistoric days state boundary lines were not a source of embarrassment. McKern (4, pp. 138-143) has suggested the possibility of an Asiatic origin for the Woodland culture pattern and the attainment of its highest development in Wisconsin and Minnesota or in territories relatively close thereto. The Mississippi culture pattern is generally considered to have reached its height in our southernmost states and as characterized in the Lower Mississippi phase. Hopewellian appears to be more ancient than Woodland in the north

(3, p. 179) and at the bottom of a suggested time horizon in the south (4, p. 271).

Hopewellian still is classified as a phase of an Unknown pattern because of its possession of both Mississippi and Woodland traits. The culture level of the Mississippi pattern apparently was much higher than that of Woodland. On the basis of present knowledge this thought is highly speculative, but, if Hopewellian be older than Woodland in the north, and the oldest suggested horizon in the south, does it not suggest the possibility of the migration northward from the south of peoples possessing an early Mississippi culture pattern? And furthermore, that when peoples having a Woodland culture pattern migrated from the north and came in contact with these Hopewellians, diffusion began its processes of interchange. An unequal population balance may have had much to do with the final outcome: Woodland traits permeated the Hopewellian phase, and, because of their superior numbers, the Woodland peoples absorbed the Hopewellians and finally destroyed the Hopewellian culture.

This suggestion is now made possible because of McKern's tentative suggestion of a migration route for the Woodland peoples from Asia via Bering Strait to the Great Lakes area by way of the Yukon and Mackenzie valleys (3, p. 142). If we may be allowed to consider time as an element in culture development, it is reasonable to believe that an earlier migration path from Bering Strait led incoming peoples to the south-southeast. It is significant that the highest culture centers created by the American Indian lay in a direct line south-southeast of Bering Strait, down along the west coast of the Americas. As against the relatively simultaneous springing up of the white man's culture centers along our eastern shores, we face the problem of the red man's migrational flow into northwestern America through a relatively narrow gateway, much the same as if all European entrance had come in by way of Labrador and the gulf of the St. Lawrence. And so in the northwest it is not unreasonable to assume the creation of advancing culture stations, primarily population stations, into which poured wave after wave of immigrants, in them to be begun the leveling processes which subsequently evolved the American Indian racial type. The suggestion made as early as 1868 (5, pp. 158-257) that the territory embracing the valley of the Columbia River and the coastal lands opposite Vancouver Island to the northward provided the natural endowments for a great prehistoric population station, is not without interest. The center of this domain is approximately two thousand miles southeast of Bering Strait. Neither in these two places, and along the vast distance between them, nor to the eastward of all that northwest country have been found, as yet, the ancient ruins of a great Indian culture rivaling the cultures developed far to the south. Some three-thousand-two-hundred miles south-southeast of Bering Strait the American Indian acquired the social technique to create a civilization of such permanency as to carry on, in some of its forms, to our present day. On to the south-southeast below the Pueblo country lay the prehistoric civilizations of Mexico, Guatemala, and northwestern South America. The Pueblo country is practically the same distance from Bering Strait as is the country bordering Lake Superior. Again, if time is a factor in cul-

tural growth, the migrations south-southeast must be assumed as earlier than those to the east-southeast of Bering Strait.

There is evidence of the migration of peoples into the lower Mississippi Valley from the west and southwest, moving into those lands where the Mississippi culture pattern achieved its highest development. This cultural horizon also predicates the necessity of time for its growth.

When we consider the Hopewellian mounds of the Ohio Valley and their cultural accessories which point toward a southern origin, we dare not think of them as the creations of some strange, unknown group, but, rather, as the work of an ethnic group or fusion of groups, at least one of which migrated out of southern culture centers characterized by the Mississippi culture pattern.

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Who Built the Mounds?

ERMINIE W. VOEGELIN, Greencastle

Since the romantic postulate of a separate race of mound builders has been abandoned, archeologists are giving increasing consideration to the possibility of determining the tribal identities of the Indians responsible for the construction of the various types of earthworks found throughout the eastern woodlands and plains areas. The literature available shows scant interest in a related question, namely, whether the remains were built by men or by women, irrespective of tribal affiliation. Superficially, one may say that archeologists generally envisage men rather than women as having engaged in construction of the earthworks;[1] perhaps such a statement represents the archeologists' real viewpoint, and the matter is not critically discussed for lack of direct evidence. There is, however, a diversity of indirect evidence which bears on this question; this evidence, which is both of an ethnographical and archeological nature, I propose to discuss under three heads.

(1) **Division of Labor.**—Among practically all of the tribes of the eastern area, men engaged in the tasks appertaining to hunting, fishing, and warfare; women were occupied with cultivating food plants, gathering wild vegetable products, preparing and cooking food, transporting burdens, procuring firewood and water, and a variety of other occupations. Man's work consisted of more strenuous, but also more intermittent labor; women's work was less arduous, but of such a nature as to keep her more or less continually occupied. This division of labor on a sexual basis was generally and consistently adhered to; the fact is amply attested in the reports of early travelers and also receives attention in ethnographic literature of the present day.[2] The general pattern, it is true, varied slightly in some of its items from tribe to tribe,[3] but essentially it prevailed as outlined above, and there is little reason to doubt that, in point of time as well as in point of wide distribution, this pattern is an old and basic feature in the cultures of aboriginal eastern America. The marked differences which exist between the aboriginal Indian pattern and that of our own culture led many early writers to characterize Indian women as "drudges," "slaves to their husbands," "submissive," etc., although such observations as the following were also occasionally offered: "the women [Dakota] . . . seem to bear their laborious lot with cheerfulness and seem to consider that department as their appropriate sphere."[4] Indian men, likewise, take

[1] Shetrone, in a general discussion of mound construction, refers to "the primitive workman" as masculine in sex (**7**, pp. 42-43) ; in referring to the Hopewell group he observes, "Each individual of the community probably contributed to the task" (**7**, pp. 193-194). Hinsdale, in computing the time required for building earthworks, deals with "one man's" probable output and the number of men required for constructing an embankment of certain dimensions (**4**, pp. 34-35).

[2] For a few of the numerous references which might be cited, see **10**, p. 139 ; **8**, pp. 384-388 ; **5**, p. 107 ; **3**, pp. 968-973 ; **9**, pp. 228-229 ; **11**, pp. 243-244 ; **2**, pp. 301-303.

[3] Among various Southeastern tribes, for example, housebuilding was a male occupation (**8**, p. 385 ; **9**, p. 229 ; **10**, p. 139), while among tribes farther north it was done mainly by women.

[4] **5**, p. 107.

quite for granted the continuous round of tasks which customarily it is the duty of women to discharge. "My mother was a good woman; she was always busy working, from sun-up all day long," a Shawnee informant commented. When it was intimated that perhaps women had the long end of the bargain, my male informant patiently elaborated on what was to him so obvious a fact. "That was what woman was created for—to take care of the man and the house, all the time."[5]

Bearing the above facts relating to the sexual division of labor in mind, let us consider certain archeological findings relating to the construction of the tumuli of the eastern and central areas. Essentially these tumuli are accretions, great or small as the case may be, of individual loads of earth. Their construction is simple; primarily they represent none-too-arduous, but sustained labor. Individuals, equipped with burden baskets or perhaps using their leather skirts as receptacles, filled their containers with earth from areas where the ground had been loosened, near the site for the mound. Each individual then carried the load of earth to the mound site and dumped it there. A single load usually weighed, according to Shetrone's measurements, 20-25 pounds; other archeologists estimate 45 pounds per load. On the larger mounds construction often continued over a period of several years; the seasonal lines on cross sections indicate where work on the mound stopped temporarily, to be resumed again later.[6]

As we have already pointed out, among the historic tribes of eastern America, women were in the habit of keeping steadily occupied with repetitious tasks of a fairly arduous nature. Working the soil and carrying burdens were, notably, feminine occupations. According to the archeological record, these two activities were precisely the major ones involved in the construction of mounds and other earthworks. Since artifacts and burials found in the mounds show that the cultures of the various tribes responsible for the tumuli were similar in fundamental respects to the cultures of historic eastern groups, it seems reasonable to infer, therefore, that the division of labor among the tribes whose cultures are known to us only through archeology, was organized on much the same basis as it was among the historic tribes.

(2) **Implements and Receptacles.**—The type of implements used in mound construction furnishes additional indirect evidence. Archeologists mention the digging stick, stone hoes, clamshells and shoulder blades of deer and elk as having been used to loosen the earth needed for the tumuli, and conical baskets as serving to carry the earth to the mound site.[7] In a source account for the Choctaw, mention is made of earth having been carried on the blade bones of the buffalo, as well as in cane baskets.[8] Parallel references for all these tools are to be found in the ethnographic literature. The digging stick, a straight three-foot shaft of wood pointed at one or both ends, the "grubbing hoe" or hack made of a forked branch with one fork cut off about five inches above the crotch, and more durable hoes consisting of a bone, shell, or stone

[5] Shawnee field notes of the author.

[6] **7**, pp. 42-44, 194 and fig. 116; **4**, pp. 34-35.

[7] **1**, pp. 269-270; **7**, p. 43, fig. 116.

[8] **10**, p. 20.

blade affixed to a straight stick handle—such were until very recently the implements used primarily by Indian women throughout the eastern and central areas for gathering wild roots and tubers or in cultivating the soil. Men used these tools rarely, if at all. In carrying burdens, women, not men, used the conical burden basket attached to a tump line which passed across the forehead or over the chest; the burden basket, it might also be pointed out, was not only used exclusively by women, but the manufacture of it, as well as of all other basketry articles, was entirely woman's concern.

Skin aprons are also mentioned as having been used to carry the earth wherewith mounds were built. Among some of the mound-building peoples wrap-around or double-apron skirts may have been worn by men as well as women; evidence from the burial of a male (?) in the Nowlin mound in Dearborn county, Indiana, suggests as much.[9] However, realistic terra cotta figurines from the Turner group in Hamilton county, Ohio, portray several male figures wearing a single garment consisting of a breechclout, whereas the only female figure shown is garbed in a wrap-around skirt.[10]

In regard to point (2) we find, then, that the implements and receptacles used in mound construction are those which, among historic tribes, women were accustomed to use in connection with their daily tasks. If the archeologists' assumption is correct that earth was also occasionally transported in a short apron-like skirt, then figures from at least one mound group show that the skirt was a woman's garment and was not, customarily, worn by the men of that particular group.

(3) **Traditions.**—In the traditions of the Choctaw, and also of the Cherokee, we have evidence which relates directly to our inquiry. To turn to the Choctaw material, in 1904 Dr. Gideon Lincecum, who, according to Swanton, "knew the Choctaw thoroughly,"[11] published a traditional account of the building, by the Choctaw, of two mounds at Nanih Waiya, in Winston county, Mississippi. In one of these mounds the Choctaw say they deposited the bones of their ancestors, which they had previous to that time packed with them for many generations. These bones, of themselves, made a large mound. Over the huge pile of bones they put cypress bark, which "was neatly placed on till the bone sacks were all closely covered in, as dry as a tent. While the tool carriers were working with the bark, women and children, and all the men, except the hunters, carried earth continually, until the bark was all covered from sight, constituting a mound half as high as the tallest fir tree."[12] At the time this mound was built, so the tradition asserts, the Choctaw were subsisting by hunting and gathering wild products; the hunters, therefore, presumably formed a goodly proportion of the male population. Bearing this point in mind, we have good reason to believe that the number of men engaged in building the mound was in

[9] **1,** p. 227-228.

[10] 7, figs. 64-65 and p. 124. Cf. also fig. 67, showing a human effigy pipe of a male figure wearing a loin cloth, which was taken from the Adena mound in Ross co., Ohio.

[11] **10,** p. 12.

[12] *Ibid,* p. 12.

all probability much less than the number of women engaged in the same task.

Relative to the second mound at Nanih Waiya, the mound upon which was placed the sacred pole which had guided the Choctaw in their migrations, we find that this mound was erected entirely by men, but that they displayed a singular ineptitude for the task. The guardian of the sacred pole suggested that certain men, "the good, lazy Ishtahullos, yushpakamini, dreamers, spirit talkers and medicine men [who] had not found it convenient to assist . . . in the contruction of the great monument for the dead" be assigned to build the mound for the pole. Accordingly, "the whole of the conjurers and sorcerers [were summoned] to commence the work. They came, but they were so extremely awkward and lazy that the work progressed quite slowly. The Ishtahullo, who was superintendent of the work, exerted his whole power to encourage them to facilitate the building of the mound. It was all to no effect. They grumbled from morning till night and moved so slowly at their work, that a child could have done as much work as they accomplished in a day. The superintendent shortened their daily supply of food. They did less work and grumbled more. He made their daily food still less. They, with but few exceptions, ran off into the woods, and scattering themselves among the camps of the hunters, sponged upon them until the hunters, becoming tired of them, drove them from their camps like dogs. They returned to Nanih Waiya,"[13] but not to labor. A council was called, at which only 30 conjurers, those known to be industrious men, appeared. The great majority of the dreamers and spirit talkers, it was soon learned, had again run off, taking some 200 women as companions, mostly young wives of men who were away hunting. Searching parties could find no trace of these "lazy, heartless" men nor of the women, and, after diligent search, reported that "the conjurers must have gone off on the wind."[14] The few industrious medicine men who had attended the council labored faithfully on the mound, however, and in due course it was completed in good style and the sacred pole set therein.

Besides the two mounds at Nanih Waiya, there is also an earthen embankment surrounding the tumuli; Choctaw tradition, as recorded by Lincecum, is somewhat indefinite as to who constructed the embankment. Over 1000 of the warriors are said to have been absent at the time it was hurriedly built; the task of laying off and superintending the work was, we are told, assigned to men, the earth for the wall itself was thrown up "by the people, old and young."[15] But if this statement is rather vague, another concerning individual burial tumuli is remarkably definite. "There are," reports Lincecum, "occasionally found among the great number of tumuli scattered over the land, mounds of larger dimensions than ordinary ones. These mounds were constructed by females. Upon the death in camp of a man who had an affectionate wife, his mourning teckchi (wife), regardless of the customary time to cry, would throw down her hair and with all her strength and that of her children would

[13] *Ibid*, p. 22-24.
[14] *Ibid*, p. 23.
[15] *Ibid*, p. 26.

carry earth, and build upon the mound as long as they could find food of any kind that would sustain life. They would then return to camp, worn out skeletons." [16]

This concludes our evidence from the Choctaw; turning now to the Cherokee, we also find among this tribe certain definite statements as to the methods of mound construction. Mooney was told that "When they were ready to build a mound they began by laying a circle of stones on the surface of the ground. Next they made fire in the center of the circle and put near it the body of some prominent chief or priest who had lately died—some say seven chief men from the different clans—together with an Ulûñsu'ti stone, an uktena scale or horn, a feather from the right wing of an eagle or great tla'nuwa . . . and beads of seven colors . . . The mound was then built up with earth, which the women brought in baskets, and as they piled it above the stones, the bodies of their great men, and their sacred things, they left an open place at the fire in the center . . ." [17]

Both the Choctaw and the Cherokee material, taken by itself, would be evidence for nothing further than the methods of mound construction for these two tribes. Taken in conjunction with the previous evidence relating to division of labor and the type of implements used, however, the traditions quoted above suggest that these were typical, rather than isolated instances.

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[16] *Ibid*, p. 21.

[17] **6**, p. 396.

PROGRAM OF THE SECTION ON BACTERIOLOGY

Chairman: H. H. POWELL, Lilly Research Laboratories

1. Concentrations of purified suspensions of the virus of vaccinia. C. A. Behrens and G. H. Echelbarger, Purdue University.

2. Responses to oral bacterial immunization against colds. H. C. Allisbaugh and L. C. Morgan, Lilly Research Laboratories.

3. On the efficacy of Merthiolate as a biological preservative after ten years use. H. M. Powell and W. A. Jamieson, Lilly Research Laboratories.

P. A. Tetrault, Purdue University, was elected chairman of the Section for 1938.

ABSTRACT

Concentrations of purified suspensions of the virus of vaccinia. C. A. BEHRENS and G. H. ECHELBARGER, Purdue University.—Suspensions of the virus of vaccinia, from which approximately 85% of the foreign matter was removed by precipitating it at its isolectric-point, were concentrated by means of vacuum distillation. Dilutions of such preparations, when injected into rabbits, gave reactions at comparable dilutions of suspensions of the original calf smallpox lymph.

Response to Oral Bacterial Immunization Against Colds

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Introduction

The common cold with its complications is a serious menace to industries, communities, schools, and individuals. Considerable evidence has been advanced within recent years to indicate that a filterable virus is involved in the causation of the disease (1, 2, 3). Protection experiments with the virus have not yet proved practical. Probably only when the virus is associated with or followed by bacterial invasion is there produced that train of sypmtoms usually recognized as a common cold. For prophylactic procedures one is forced to rely upon the employment of bacterial antigens. Inasmuch as the severe symptoms are probably referable to bacterial invasion, such a course is logical.

A bacterial vaccine for prophylactic use against colds should be a very broad antigen which is capable of being conveniently administered throughout the cold season. Bailey and Shorb (4) placed considerable significance on cultures containing heterophile antigen in producing a non-type-specific immunity against pneumococci. They demonstrated this antigen in pneumococci and were able to protect rabbits against living Type I pneumococci by previously immunizing them with heterophile antigen obtained from sheep red blood cells. They likewise demonstrated the presence of heterophile antigen in organisms, other than pneumococci, that are associated with upper respiratory diseases.

Powell (5) has shown that the heterophile antibodies can readily be produced even when the antigen is administered by the oral route.

Rockwell, VanKirk, and Powell (6, 7) have reported success in prevention of colds with an antigen, administered orally, prepared from organisms associated with upper respiratory diseases and having a high heterophile antigen content. Their work has since been confirmed (8).

Experimental

a. Vaccine Preparation.—Strains of pneumococci, streptococci, *H. influenza* and *N. catarrhalis* were tested for heterophile antigen by immunizing rabbits with heat-killed suspensions and titrating the sera for presence of heterophile antibodies. Only those cultures of demonstrated high heterophile antigen content were selected for preparation of the vaccine employed in this study. Table I shows a typical test for heterophile antigen in the pneumococcus cultures. Only four of the nine strains tested contained sufficient heterophile antigen to be used in the vaccine.

TABLE I.—Test of Pneumococcus Cultures for Heterophile Antigen

		Titer Before Immunization				Titer After Immunization						
Culture	Rabbit	32	64	128	Control	32	62	128	256	512	1024	Control
Park I	198	+++	+	—	—	++++	++++	++++	++++	++++	+++	—
Parker II	178	+	—	—	—	++	+	—	—	—	—	—
Park III	177	+	—	—	—	++	+	—	—	—	—	—
DR I	176	—	—	—	—	++++	++++	++++	++++	++++	++++	—
Boston I	173	++	+	—	—	++++	+++	++	+	—	—	—
Boston II	171	+	—	—	—	++++	++++	++++	++++	++++	+++	—
Strain V	168	—	—	—	—	+	—	—	—	—	—	—
Strain VIII	167	+	—	—	—	++	+	—	—	—	—	—
Cooper IV	165	—	—	—	—	++++	++++	++++	++++	++++	++++	—

The bacteria used in the vaccine were cultivated on suitable solid media, washed off with physiological saline, heat-killed, and tested for sterility by inoculation on media favorable to the growth of the particular organisms involved. After sedimenting the organisms by centrifugation, they were adsorbed on starch, dried, and filled into capsules. Each lot of filled capsules was tested on rabbits for ability to incite heterophile antibodies and on mice and guinea pigs for safety. Each capsule contained 25 billion pneumococci, 15 billion streptococci, and 5 billion each of *H. influenza* and *N. catarrhalis*.

b. Human Immunization.—This vaccine was administered to 129 individuals, and a group of 129 who were of similar age, working and living under similar conditions, were selected as controls. Treatment consisted of taking one capsule daily for seven days and one or two capsules weekly throughout the duration of the experiment. The capsules were administered with a glass of cold water at least 30 minutes before breakfast. Blood samples were taken from this group before the beginning of the treatment and again on the third to fifth day after the seventh capsule had been taken. The blood sera were tested for heterophile antibodies and streptococcus agglutinins.

c. Serological Study.—The results of the heterophile antibody titrations are given in Table II. Analysis of this table shows that 37.5% of

TABLE II.—Heterophile Antibody Titration on 112 Individuals

Before Immunization

Titer	0 to 40	40	80	160	320	640
Individuals	42	32	20	7	9	2

After Immunization

Titer	0 to 40	40	80	160	320	640
Individuals	12	15	29	35	15	6

this group had a titer of less than forty, and 16.1% had a titer of one hundred and sixty or above before treatment. After treatment 10.7% had a titer less than 40, and 50% had a titer of 160 or over.

Tables III and IV show the results of the streptococcus agglutinations. The tests shown in Table III were made using a mixture of two *Strepto-*

coccus viridans cultures as the antigen. Before immunization 90% of the group had a titer of less than 40, and 10% had a titer of 40; while after treatment 27.5% had a titer of less than 40, and 65% had a titer of 80 or more. The tests shown in Table IV were made using the three

TABLE III.—Streptococcus Agglutination on 40 Individuals Using Two Cultures of Streptococcus Viridans

Before Immunization

Titer	0 to 40	40	80	160	320
Individuals	36	4	0	0	0

After Immunization

Titer	0 to 40	40	80	160	320
Individuals	11	3	18	8	1

TABLE IV.—Streptococcus Agglutination Tests on 45 Individuals Using Each Type Separately (Hemolytic, Viridans, and Indifferent)

Before Immunization

Titer	0 to 40	40	80	160	320	
Hemolytic	27	12	3	3	0	
Viridans	34	7	2	2	0	
Indifferent	23	15	4	3	0	

After Immunization

Titer	0 to 40	40	80	160	320	640
Hemolytic	18	3	4	8	9	3
Viridans	6	5	18	11	5	0
Indifferent	3	2	6	6	13	15

types of streptococci separately. Before immunization the percentage of the group having a titer of 160 or over was 7.5% for hemolytic, 5.0% for viridans, and 7.5% for indifferent. After treatment the percentage having the same titer was 50% for hemolytic, 40% for viridans, and

85% for indifferent. The sera of all individuals in this group agglutinated some type of streptococci after treatment.

d. Clinical Study.—The control and experimental groups were observed for colds from November 10, 1935, until March 10, 1936. In evaluating the data obtained, it was necessary to divide the individuals into groups on the basis of the number of capsules they had taken since a considerable number failed to follow the treatment during the whole period. Table V shows that, although a large number of individuals failed to continue the treatment, the number of colds experienced by the

TABLE V.—Clinical Study
November 10, 1935 to March 10, 1936
129 patients—129 controls

Experimental Group				
Number of Capsules Taken	Patients	Colds	Days Duration	Colds per Person
1–10	35	32	507	.94
11–20	59	49	398	.83
21–30	17	13	63	.76
30 or more	18	5	90	.28
Totals	129	99	1058	.70

Control Group				
Patients	Colds	Days Duration	Colds per Person	Percent Reduction
35	41	444	1.17	19.6
59	62	671	1.14	27.2
17	24	248	1.41	46.1
18	22	166	1.22	77.7
129	148	1529	1.24	33.1

experimental groups was 33.1% less than that by the controls. The minimum reduction was 19.6% and the maximum 77.7%.

Summary

This paper presents additional evidence that a vaccine, prepared from bacteria associated with upper respiratory diseases and having a high heterophile antigen content, is of value in preventing colds. Such a vaccine, administered orally, causes a rapid increase in heterophile antibodies and also streptococcus agglutinins.

The results of the clinical study indicate that those individuals who rigidly followed the treatment according to directions were benefited more by the vaccine than those who were prone to be somewhat lax.

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On the Efficacy of "Merthiolate" as a Biological Preservative After Ten Years' Use

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Introduction

The ideal antigen or antibody preparations for active or passive immunization of humans would comprise unpreserved native suspensions or solutions of determined potency, and thus the artificial process would closely simulate natural immunization. Since there are so many hazards connected with non-preservation, practically the entire commercial usage of vaccines and antisera has been confined to preparations containing added antiseptics. Such antiseptics must be tolerated constantly by the vaccine or serum for their action in preventing chance contamination. Criteria of their usefulness, therefore, include both the extent of undesirable action on the preserved substance and the extent of desirable action upon the chance organisms which may be encountered. Obviously a combination of characteristics, including in addition to a low degree of toxicity a minimum of injury to antigen or antibody and a maximum bacterial devitalizing action, would indicate the most useful preservative inasmuch as no perfectly selective ideal preservative has been described.

Review of Preliminary Reports

In early observations upon biological properties of "Merthiolate" (Sodium Ethyl Mercuri Thiosalicylate, Lilly), we (1) noted rather strong antiseptic effects on several pathogens and a marked degree of freedom from precipitating action against blood proteins, egg albumin, etc. Upon injection into mice, guinea pigs, rats, rabbits, dogs, and humans, "Merthiolate" was found to be much better tolerated than other similar substances. These properties indicated the use of "Merthiolate" as an antiseptic for human application and as a better preservative for vaccines and sera than the phenoloid compounds, the toxicity of which was reported upon several years ago by Leake and Corbitt (2). It may be mentioned that phenoloid toxicity has been emphasized recently in a critical discussion of preservatives for biological products (3). Also, a moderately rapid disappearance of phenoloid preservative from biological products through combination with rubber stoppers has been shown very recently (4).

In reports of early experiments with "Merthiolate" as a preservative, we (5) have called especial attention to the better keeping qualities of vaccines and antisera when preserved with "Merthiolate" instead of the phenoloid preservatives. Subsequent experimental and routine use of "Merthiolate" in this way has been made by various laboratories.

Our own biological preservative practice comprises mainly the use of "Merthiolate" 1-10,000 concentration in various vaccines and sera and

to a lesser extent the use of "Merthiolate" 1-500,000 concentration in a series of Undenatured Bacterial Antigen preparations.

Our stock preservative solution is 1% "Merthiolate." From this stock the desired quantities are pipetted into the vaccines or sera to be preserved, and in attaining a "Merthiolate" 1-10,000 preservative concentration for example, 1 cubic centimeter of the stock solution suffices for each 100 cubic centimeters of material to be preserved. While any convenient stock preservative solution of "Merthiolate" may be used, even 1-1,000, a 1% stock solution, is sufficiently concentrated to avoid introducing appreciable dilution of antitoxin etc. in the process of adding the preservative.

"Merthiolate" has a rather strong bacterial inhibitory property. Due regard for this should be made in culturing "Merthiolate"-preserved vaccines and sera into the necessary media for sterility examination, and some of the inocula should be near or above the range of one one-hundredth the volume of the medium into which they are planted. If the original preservative concentration, therefore, is 1-10,000, the final concentration of preservative in the sterility-test culture medium of infusion broth will be 1-1,000,000, which will scarcely inhibit the growth of viable organisms, if present, when the sterility-test cultures are incubated the usual seven days. It has been reported (**6**) that in some cases agar may be better than broth for use in sterility proving of vaccines and sera.

It is preferable that rubber stoppers to be used in vaccine and serum vials be free of excess sulphur. This may be made certain by first boiling them in dilute solution of sodium hydroxide and then in several changes of wash water. Excess of sulphur, if left in rubber stoppers, will occasionally cause discoloration of solutions preserved with "Merthiolate" through interaction with the preservative. A recent note on such discoloration has been published by Sickles (**7**).

Subsequent Comparative Laboratory Experiments

The earlier reports on better keeping qualities of "Merthiolate" as against phenoloid preserved antigens and antibodies have been verified and amplified by several experimenters. This is true of particularly careful studies of Rosenstein and her associates (**6**). These authors have dealt with the problem of rendering the vaccine or serum self-sterilizing against varied amounts of artificially introduced contaminations. For this combined use they preferred "Merthiolate" 1-10,000 for antigen preservation, and, rather than use "Merthiolate" 1-5,000, which alone was necessary for sterilizing and preserving their antisera, they preferred a mixture of "Merthiolate" 1-20,000 plus 0.25% phenol. Still weaker mixtures were later experimented with, and the mixed preservatives appeared to fortify each other. Rosenstein and Levin believed "Merthiolate" 1-5,000 was contraindicated in antisera since these are frequently administered in large doses. In view of the fact that human adults repeatedly tolerate over 250 milligrams of "Merthiolate" intravenously and that one would scarcely attain a toxic dose of "Merthiolate" 1-5,000 in antiserum until theoretically after more than 1,000 cc. of such serum had been used, we first utilized this concentration as wider margin

of preservative safety in the commercial preparation of antisera. A routine use for two years of "Merthiolate" 1-5,000 in this way elicited no reports of undesirable preservative reactions in humans. Later, however, we have used "Merthiolate" 1-10,000 since experience has indicated little need and some contraindication of making these antisera so strongly self-sterilizing. It appears that large numbers of contaminants or their products should be prevented from appearing in antiserum previous to the addition of the preservative. If this is not done, initially contaminated sera, even if subsequently rendered sterile through the action of the preservative, on injection often produce added chills and fever.

Wadsworth and his associates (8) in a report on purification of diphtheria toxoid have dealt in part with "Merthiolate" 1-10,000 and phenol 0.4% as preservatives. Data on comparative preservative effects on stability over a long period of time or age are lacking. These authors indicate, however, that, when frozen at –10° C. for twenty hours, the flocculating value of phenol-preserved toxoid was almost completely destroyed, while that of "Merthiolate"-preserved toxoid was unaffected. Watson and Langstaff (9) previously observed this phenomenon with phenol-preserved toxoid, and related phenomena have been observed in toxin-antitoxin mixtures.

Scherp and Rake (10) in a report on concentration and standardization of antimeningococcus serum have noted better keeping qualities of serum preserved with "Merthiolate" 1-10,000 as compared to serum preserved with 0.3% tricresol. For example, the former serum showed no change in antibody content after storage at 0°–4° C. for six months as compared to losses of 13% to 19% appearing in the tricresol-preserved serum under the same conditions.

Douglas and Hartley (11) have shown in comparative experiments that "Merthiolate" 1-5,000 devitalizes tubercle emulsions containing 1 mg. moist tubercle bacilli per cc. in less than one day and that "Merthiolate" 1-10,000 is effective in this way in four days. This is to be compared with phenol 0.5%, which is not effective up to fourteen days. As proof of devitalization, these authors injected fifty-nine guinea pigs with various doses of the medicated emulsions and observed these for a year. At this time the test animals reacted negatively to OT and subsequently when autopsied showed no tubercular lesions.

Eldering and Kendrick (12) have reported upon the preparation of Phase I pertussis vaccine and have dealt with its keeping qualities and the effects of the preservatives in the course of time in bringing about depression in immunizing action. These authors have noted that "Merthiolate"-preserved vaccine did not show as marked changes in agglutinin production after storage as did phenol preserve vaccine. At this time no information is available regarding the comparative human protection conferred by the "Merthiolate"- versus phenol-preserved vaccines made by Eldering and Kendrick. Previous to knowledge concerning phase relationship of *H. pertussis*, we had observed that stronger agglutinins were produced by "Merthiolate"-devitalized than by heat-devitalized pertussis vaccine.

Krueger and Nichols (13) in experimenting with undenatured bacterial antigens prepared from staphylococci and preserved with phenol,

tricresol, and "Merthiolate," have found "Merthiolate" caused the least denaturation. Tricresol 0.3% and phenol 0.5% produced 50% and 48% denaturation, respectively, as compared to "Merthiolate" in concentrations of 1-10,000, 1-20,000, and 1-50,000, which produces in these three concentrations 37%, 27%, and 24% denaturation, respectively. These native antigens are labile to the extent that thermal denaturation begins to be significant at 40° C. and hence responds very rapidly to denaturing influences.

Use of "Merthiolate" in Special Antigens, Sera, and Solutions

During the last few years many experimenters have used "Merthiolate" in preserving vaccines and antisera in small amounts for laboratory purposes. Although little comparative data are available in most of these brief references, little or no denaturation has been reported in any instance. However, several reports including quantitative data may be referred to as follows.

Kuhns (14) has used "Merthiolate" 1-10,000 to devitalize meningococcus cultures and to preserve various culture antigens used for diagnostic and immunizing purposes in several hundred human subjects. As shown in a comparative way with suitable controls, this preservative caused no "non-specific" or undesirable reactions in any of the subjects. Comparative information on the effect of the preservative on the various antigens was not shown; however, the degree of stability of the antigens appeared to indicate their clinical usefulness.

Hecht, Rappaport, and Briggs (15) have experimented with "Merthiolate" as a sterilizing agent for protein solutions prepared for allergic skin tests and treatments. They have used "Merthiolate" 1-3,000 successfully for this purpose, and after exposure to this concentration of antiseptic for twenty-four hours a 50% dilution of the preparation is accomplished by the usual addition of glycerin, giving a stock solution containing "Merthiolate" 1-6,000. These authors have also found in controlled precipitin tests with rabbit antisera that concentrations of "Merthiolate" even up to 1-1,000 caused no denaturation or alteration of 1% egg albumin solution during three months time.

Davis (16), in investigating the preparation of sterile solution, has given some attention to the action of "Merthiolate" as a preservative. He states that the alkalinity of this antiseptic makes it unadapted to the preservation of hypodermic drug solutions but that it lends itself to use as a biological preservative. His tests indicate that "Merthiolate" 1-100,000 would be a more potent germicide than 0.5% phenol or 0.3% tricresol.

Laidlaw, Smith, Andrews, and Dunkin (17), in preparing horse antiserum against human influenza virus, have used "Merthiolate" 1-20,000 as a preservative. This has at least a twenty-fold margin of safety in noninterference in serum-virus neutralization tests. In other words, the preservative does not in itself inactivate the virus in any serum-virus mixtures prepared in laboratory tests.

In this connection it may be mentioned that "Merthiolate" also does not markedly inactivate vaccine virus or poliomyelitis virus, while rabic virus and phage appear to be only moderately inactivated, and in turn

horse encephalomyelitis virus appears to be readily inactivated by "Merthiolate" treatment. Apparently the antiviral action differs from one virus to another just as with other antiseptics. For example, phenol 0.5% has been used for many years as a preservative of commercial vaccine virus, which in the form of a "live" virus is scarcely affected in potency by the phenol. Similar application of phenol preservative to phage results in critical loss in titer.

In experiments bearing partly on intravenous antisepsis and somewhat on the use of "Merthiolate" as a preservative, Smith, Czarnetzky, and Mudd **(18)** have indicated a large amount of coupling and inactivation of mercurials, including "Merthiolate," with serum. Their main interest appeared to be on the use of conventional antiseptics intravenously, and their results contraindicated such use. However, we believe such use has not been proved in direct experiments in infections, and hence "Merthiolate" has not been recommended in this way. It might be stated that, in light of the rather feeble "test tube" potency of sulfanilamide and the phenomenal "in vivo" curative action of this drug, intravenous excellence could hardly be proved or disproved by the technique used by Smith and her associates.

In experiments bearing directly on the comparative lasting qualities of "Merthiolate" as a preservative, we have shown in a separate report **(19)** that "Merthiolate" lasts in this way fully three years and that diminished activity is demonstrable after seven years. This is to be contrasted to the rapid drop in titer of phenoloid preservatives.

Summary

About ten years ago we started to experiment in a comparative way with the use of "Merthiolate" as a preservative agent for vaccines and sera. The results were sufficiently good to lead us to introduce routine biological preservation with "Merthiolate" two years later. Eight years have now elapsed since "Merthiolate" was first used commercially in this way. The degree of its usefulness in this field is attested by the experiences of other workers as well as ourselves. References to these have been made in the preceding paragraphs, and most of these reports are quantitative and comparative. It is believed that the papers which have been cited verify conclusively the usefulness of "Merthiolate" as a biological preservative first introduced ten years ago.

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The following, included in the titles of papers in the foregoing references, is a trademark which identifies a product of Eli Lilly and Company:
"Merthiolate" (Sodium Ethyl Mercuri Thiosalicylate, Lilly).

PROGRAM OF THE SECTION ON BOTANY

Chairman: C. L. PORTER, Purdue University

1. Notes on the distribution in Indiana of Quercus Shumardii Buckley and its so-called variety Schneckii (Britton) Sargent. Ralph M. Kriebel, Newcastle.
2. Dioecism in Carex picta. Louis Martens, Indiana University.
3. Distribution of Lemanea in relation to geological formations in southern Indiana. C. M. Palmer, Butler University.
4. Notes on Indiana grasses, 1937. J. E. Potzger, Butler University.
5. Recent additions to the flora of Indiana. R. M. Tryon, Jr., Madison, Wisconsin.
6. Studies in Indiana Bryophytes II. Winona H. Welch, DePauw University.
7. Another photoelectric device for measuring leaf areas. Raymond E. Girton and Carl H. Gardner, Purdue University.
8. A note on Stemonitis fusca Roth. William D. Gray, University of Pennsylvania.
9. Notes on Indiana fungi, 1937. M. L. Lohman, Indiana University.
10. Studies on control of tulip blight. A. T. Guard, Purdue University.
11. Exposure of fungus organisms to ultra-violet irradiation. J. Emmert Young, Purdue University.
12. Effect of oxygen on inhibition of fungi. R. D. Zumstein, Purdue University.
13. Some acidity studies of dunes and bogs. J. E. Potzger, Butler University.
14. The acidity and moisture content of tree bark. Charlotte Young, Butler University.
15. Pollen study of Cranberry Pond near Emporia, Madison County, Indiana. Jean Paul Barnett and J. E. Potzger, Butler University.
16. Fossil pollen analysis of Fox Prairie Bog, Hamilton County, Indiana. Robert L. Prettyman, Butler University.
17. Pollen spectrum of Lake Cicott Bog, Cass County, Indiana. William M. Smith, Butler University.

The paper by E. R. Smith on hay fever, an abstract of which is included here, was read in the General Session of the Academy.

Floyd E. Beghtel, of Evansville College, was elected chairman of the Section for 1938.

ABSTRACTS

Notes on the distribution in Indiana of *Quercus Shumardii* Buckley and its so-called variety *Schneckii* (Britton) Sargent. RALPH M. KRIEBEL, Newcastle.—These oaks have not been fully understood in Indiana. Until about 1932, authentic collections had been made by

others in seven counties, mostly in the southwestern part of the state. At that time the writer started the collection of herbarium specimens and other data pertaining to the species and its so-called variety. Specimens taken from one to eight trees in each of 64 counties are in his herbarium, and duplicates of most of them were deposited in other Indiana herbaria, as well as in several larger ones outside the state.

Based upon the material collected and observations made in the field, it is contended that the trees answering the description of the species and the variety, having so many characteristics in common, should be considered one species with different modes of expression. The shape of the cup, upon which the difference is based, varies greatly. Intermediates of all degrees can be found which seem to be merely indefinite forms.

Dioecism in Carex picta. LOUIS MARTENS, Indiana University.—Carex picta characteristically forms circular clumps, each consisting of one plant with a shallowly imbedded rhizome system from which vegetative and fertile shoots arise. The flowers are imperfect. They mature in March and April. The male flowers are composed of three stamens, the female of a tricarpellate pistil. Each type of flower represents a highly evolved floral unit. Generally 40 to 60 of these florets are aggregated in a spike-like inflorescence of problematical morphological nature. As a rule, each individual clump is unisexual and remains of the same sex year after year, but a few instances were observed where the staminate inflorescences were attached to a male plant, and the pistillate to a female plant. Most of the individuals bloom regularly year after year. Those remaining sterile for a period resume their previous sexual expression without apparent alteration. Plants grown in the greenhouse for three years showed no alteration of sex. In four years of observations the only deviation recorded was in the form of an inflorescence of staminate form and heritage with one pistillate floret having replaced a staminate one. These observations show remarkable stability in the sexual expression of this dioecious Carex, and, although sex reversal does occur, it is very rare.

Distribution of Lemanea in relation to geological formations in southern Indiana. C. M. PALMER, Butler University.—An extensive study of the distribution of Lemanea in Indiana has shown that it is definitely limited to the upper Mississippian, the lower Devonian, and the Silurian limestone regions in the southern part of the state. Seventy locations have been found, the largest number being Jefferson and Jennings Counties. The rocks of the Ordovician, Knobstone, and Pennsylvanian regions are apparently unsuitable for its growth.

Another photoelectric device for measuring leaf areas. RAYMOND E. GIRTON and CARL H. GARDNER, Purdue University.—A simple and inexpensive apparatus has been constructed for the rapid measurement of leaf areas. Important features of this apparatus include the following: A small rheostat is built into the lighting circuit so as to permit the adjustment of the intensity of the light source which will otherwise change with line-voltage fluctuations. A "photo flood" reflector is employed for collecting and directing the light rays on to the leaves. Light

intensities are measured by a Weston "phototronic" cell and millivoltmeter circuit. Correction for light transmission by leaves of different types is made with the aid of an original calibration curve.

Studies on control of tulip blight. ARTHUR T. GUARD, Purdue University.—Investigations were made to test the possibilities of naphthalene and formaldehyde as fungicides for the control of tulip blight. Bulbs were treated with formaldehyde and then planted in clean soil. Bulbs were planted in both clean and inoculated soil with a part of each plot treated with naphthalene. The 2% formaldehyde used killed both the mycelium and the sclerotia of *B. tulipae*. Naphthalene completely inhibited their growth, but it was not lethal to either. Neither was injurious to the bulbs in the concentrations used.

Pollen study of Cranberry Pond near Emporia, Madison County, Indiana. JEAN PAUL BARNETT and J. E. POTZGER, Butler University.—A pollen study was made in one of the southernmost areas in the late Wisconsin glacial deposits in Indiana. The bog was filled in 31 feet at the greatest depth. The pollen spectrum indicates the following succession of forests: (based on a count of 200 pollen grains for each foot level) Picea-Abies to Quercus-Larix-Pinus to Quercus-Carya to Quercus-Acer. Pine occurs in all levels of the peat but was not a constituent of the forest when settlers moved into the area a hundred years ago.

Fossil pollen analysis of Fox Prairie Bog, Hamilton County, Indiana. ROBERT L. PRETTYMAN, Butler University.—Fox Prairie Bog, one mile north of Noblesville, Indiana, was found to be 40 feet deep, having 29 feet of peat and 11 feet of marl. The upper 12 feet of peat were deposited during a period unfavorable to the preservation of pollen grains. The pollen grains identified and counted revealed a coniferous forest dominated by Abies and Picea in the lower levels of marl. The transitional period from coniferous to broad-leaved forest was gradual and was characterized by Pinus and Larix maxima and the general increase of broad-leaved genera. The broad-leaved forest which followed the transitional period was essentially oak-hickory, followed by indications toward the present day beech-maple climax. The successive forest types indicate the following fluctuations in climate: cool moist, warm dry, cool moist, warm dry, and warm moist.

Pollen spectrum of Lake Cicott Bog, Cass County, Indiana. WILLIAM M. SMITH, Butler University.—The bog was filled 31 feet, and the peat was underlain by 3 feet of marl. The pollen analysis indicates the following forest succession for Cass County: a Canadian type of coniferous forest dominated by Abies and Picea in the lowest three feet; Pinus, Betula, and Quercus from 29 ft. to 26 ft.; a dominance of Pinus from 26 ft. to 22 ft.; and a rapid change to Betula-Quercus, with Quercus and Carya forming the climax, and Ulmus and Juglans the sub-climax, from 19 ft. to 1 ft.

Notes on a suggested treatment for fall hay fever. ERNEST RICE SMITH, DePauw University.—The widespread distribution of fall hay fever, its symptoms, and common methods of treatment are outlined. One of the latter is the use of honey, which in the case of the writer

had absolutely no effect. A study of the use of *fall* honey, however, indicates some success in the control of fall hay fever. The dosage used in moderate cases is as follows: Beginning May 1 and through the month, two teaspoons as full as may be moved from honey jar to dish, (approximately 40 g.) per day; for the month of June, three teaspoons; and from July 1 through the hay-fever season, four teaspoons. Where marked aversion to the strong fall honey is felt or where the case is very severe, probably year-round immunization would be advisable. A dosage of one teaspoonful per day from November 1 to May, with increased amounts thereafter, is being tried in one case. The fall honey will have to be obtained directly from the apiary, taken from the hives either late in the fall or early the following spring. As far as the writer knows there is practically no fall honey on the market. It is so strong that it is usually re-fed to the bees in the spring. Because of limited amounts of available honey, I have data on but six cases. Of the six who meticulously followed the above routine, two cases were almost perfectly successful. One, sickened by the strong honey, dropped treatment at an early state and is now testing the year-round immunization. The other three showed but slight improvement. It is to be hoped that anyone who is interested in the above study of a possible treatment of fall hay fever, and is willing to aid in its study, will keep a record of data connected with actual cases—dates, dosages, severity, some estimate of abundance of ragweed, etc., and report to the writer.

Notes on Indiana Grasses, 1937

J. E. Potzger, Butler University

This is the sixth contribution of a series of annual reports on Indiana grasses previously unreported for the counties specified. The nomenclature is that of Hitchcock's Manual of Grasses of the United States, 1935. Each county record carries the author's collection number. A specimen of each grass reported was deposited in the Butler University herbarium. *Agrostis hiemalis* (Walter) B.S.P., Lagrange, 7496. *Agrostis Elliottiana* Schultes, Madison, 7453. *Aristida longespica* Poiret, Harrison, 7735, Perry, 7747, Spencer, 7791. *Aristida intermedia* Scribner & Ball, Orange, 7418. *Aristida ramosissima* Engelman, Jackson, 7700. *Bromus purgans* L., Madison, 7456. *Bromus secalinus* L., Madison, 7465. *Dactylis glomerata* L., Madison, 7442. *Diarrhena americana* Beauv., Crawford, 7739. *Digitaria filiformis* (L.) Koeler, Perry, 7754, Spencer, 7801. *Digitaria Ischaemum* Schreber, Harrison, 7842, Washington, 7711. *Echinochloa crusgalli* (L.) Beauvois, Warrick, 7809. *Eleusine indica* (L.) Gaertner, Orange, 7823. *Elymus villosus* Muhl, Orange, 7824. *Elymus virginicus* L., Jackson, 7691. *Eragrostis capillaris* (L.) Nees, Perry, 7760, Warrick, 7814. *Eragrostis spectabilis* (Pursh) Steudel, Harrison, 7714, Orange, 7417, Spencer, 7787. *Festuca obtusa* Sprengel, Madison, 7445. *Festuca rubra* L., Noble, 7483. *Leersia lenticularis* Michaux, Spencer, 7805. *Leersia oryzoides* (L.) Swartz, Harrison, 7729, Spencer, 7780. *Muhlenbergia mexicana* (L.) Trinius, Warrick, 7807. *Muhlenbergia sobolifera* (Muhlenberg) Trinius, Morgan, 7427. *Muhlenbergia tenuiflora* (Willd.) B.S.P., Jackson, 7692, Marion, 7420. *Panicum Boscii* Poiret, Perry, 7763. *Panicum capillare* L., Harrison, 7715, Orange, 7837, Perry, 7750. *Panicum clandestinum* L., Madison, 7455. *Panicum dichotomiflorum* Michaux, Washington, 7708. *Panicum Gattingeri* Nash, Orange, 7839, Warrick, 7808. *Panicum huachucae* Ashe, Madison, 7458, Spencer, 7802. *Panicum philadelphicum* Bernardi, Perry, 7759, Spencer, 7781. *Paspalum pubescens* Muhlenberg, Jackson, 7698, Orange, 7415, Scott, 7705. *Poa pratensis* L., Madison, 7443. *Setaria lutescens* (Weigel) Hubbard, Harrison, 7726, Perry, 7756. *Setaria viridis* (L.) Beauv., Orange, 7826. *Sphenopholis intermedia* (Rydb.) Rydb., Madison, 7441. *Sporobolus asper* (Michaux) Kunth, Crawford, 7425, Harrison, 7852, Wabash, 7425. *Sporobolus neglectus* Nash, Harrison, 7852.

Recent Additions to the Flora of Indiana

R. M. Tryon, Jr., Chesterton

I wish to report the following additions to the flora of Indiana:

Potamogeton epihydrus Rafinesque

Collected in State Line Creek, Michiana Shores, La Porte Co., Aug. 8, 1936, No. 2,653. Identified by Chas. C. Deam, confirmed by M. L. Fernald. Abundant at the concrete bridge where the main entrance road crosses the creek and farther east by a wooden bridge where a cinder road crosses the creek. Floating leaves few, mostly opposite, oblong, tapering into the petiole; submersed leaves linear, less than 1 cm. broad, up to 14 cm. long, alternate, two-ranked, a coarsely cellular-reticulated space between the inner nerves and the midrib. The cellular-reticulated space is characteristic and especially clear in fresh material.

Asplenium platyneuron f. *serratum* (Miller) Hoffmann

Collected on the bluff of the Ohio River 3 miles east of Cannelton, Perry Co., Aug. 20, 1936, No. 1,937, and on a hillside in the Martin County State Forest, Martin Co., July 4, 1937, No. 3,208. Only one plant was found in each locality. The Perry County plant was a very large specimen having seventy fronds. This form is characterized by rather long, narrow pinnae that are coarsely and often irregularly toothed. The larger teeth may be slightly incised.

Ophioglossum vulgatum f. *pseudopodum* Blake

In swamps in the northern part of the state: 1½ miles north of Lydick, St. Joseph Co., July 21, 1936, No. 2,384½, July 1, 1937, No. 3,172; north bank of the Grand Calumet River near the western edge of Gary, Lake Co., July 8, 1936, No. 2,382½; and Indiana Dunes State Park, Porter Co., June 27, 1937, No. 3,309. This form is likely to be found wherever the species is abundant. The sterile blade is borne on a narrowed base that is from one-fourth to two-thirds as long as the blade proper, which is often elongated. Blake (Rhodora 15:87. 1913) gives a good figure of this form. The narrow base and often elongated blade suggest that this form is a result of a response to light conditions when the plant is growing among tall herbage. However, while all of the f. *pseudopodum* I have found has been growing in rather tall and dense vegetation, the typical species is always more common in such a habitat. Perhaps only the more genetically plastic plants react to the environment in this way.

Botrychium dissectum f. *oneidense* (Gilbert) Clute

Indiana Dunes State Park, Porter Co., 1932, No. 744. Woods on Beverly Shores adjacent to the southeast corner of the Indiana Dunes State Park, Porter Co., 1934, No. 792. Identified by C. A. Weatherby. Chas. C. Deam has specimens from DeKalb, Howard, and Steuben counties. This form grows on the higher parts of rich low woods. In general, the plant is coarser, that is, the segments are broader and cut

less than in f. *obliquum*. The tips of the segments are slightly pointed or obtuse. This form was reported for Indiana first by Tryon in Amer. Midl. Nat. 17:429. 1936.

Dryopteris Goldiana (Hooker) Gray *X Dryopteris marginalis* (Linnaeus) Gray

On the south bluff of White River just north of the Martin County State Forest, Martin Co., Aug. 20, 1935, No. 2,015, July 4, 1937, No. 3,219. Identified by E. T. Wherry. This hybrid was found growing on a rich, damp, shady, rocky bluff where *Dryopteris Goldiana* and *Dryopteris marginalis* were abundant. Although collected in 1935, this fern was not recognized until this year when E. T. Wherry identified it while looking through the ferns in the herbarium of Chas. C. Deam. The writer went to the locality in the hope of finding more of the hybrid and was fortunate enough to find six plants. Within the last year about one-half of the trees have been cut off the bluff, markedly changing the habitat so that this fern may not long survive. The *Dryopteris Goldiana* has already suffered considerably. The general aspect of the plant is different from either of the parents. The sori are borne midway between the midvein and margin, the sori of *Dryopteris marginalis* are borne on the margin, and those of *Dryopteris Goldiana* are near the midvein. The pinnules are crenulate, pinnatifid, or deeply pinnatifid, usually more deeply cut than in typical *Dryopteris Goldiana*, but never so deeply cut as in *Dryopteris marginalis*. The basal pinnae are usually wider at the middle than at the base as in *Dryopteris Goldiana*, but they may be wider or almost as wide at the base as in *Dryopteris marginalis*. The scales on the lower part of the stipe are dark brown with a light brown margin, typical of *Dryopteris Goldiana*.

X Dryopteris Boottii (Tuckerman) Underwood

Indiana Dunes State Park, Porter Co., Sept. 5, 1935, No. 2,340, and Michigan Shores, La Porte Co., July 22, 1936, No. 2,387. Identification confirmed by F. K. Butters. This hybrid grows in rich wet woods where *Dryopteris cristata* (Linnaeus) Gray and *Dryopteris spinulosa* var. *intermedia* (Muhlenberg) Underwood are common. The frond is widest at the middle and narrowed toward the base, longer and narrower than *Dryopteris spinulosa* var. *intermedia*, broader than *Dryopteris cristata*. The cutting of the frond is half way between *Dryopteris cristata and Dryopteris spinulosa* var. *intermedia*. The indusium is glandular as in *Dryopteris spinulosa* var. *intermedia*. The glandular indusium separates this hybrid from the closely related *Dryopteris cristata* X *Dryopteris spinulosa*.

Studies in Indiana Bryophytes II

WINONA H. WELCH, DePauw University

The mosses used in this study are Indiana collections in herbaria in the following institutions: Indiana University, Butler University, DePauw University, Field Museum of Natural History, University of Illinois, University of Wisconsin, and University of Chicago; and the personal herbaria of the following: Chas. C. Deam, J. P. Naylor, and the author. The collections presented to the author by Chas. C. Deam, R. M. Kriebel, William D. Gray, Harriet Gragg Winch, and Earl L. Harger, Jr. have contributed considerably to the range of distribution.

The nomenclature is that of A. J. Grout, The Moss Flora of North America North of Mexico 1:28-61. 1936; 77-99. 1937.

The distribution of each species is based largely upon Indiana specimens examined by the author and is shown by the list of counties in which collected. The asterisk preceding the name of a county indicates that the species has been reported from that locality according to published records but not studied by the author.

The asterisk following the name of a species or a variety is an indication that, according to available literature, this is the first published record for Indiana.

All of the author's collections of bryophytes since May, 1937, have been made with the financial assistance of an Indiana Academy of Science Research Grant through the American Association for the Advancement of Science. The writer wishes this acknowledgment to be a sincere expression of her very deep appreciation of this gift.

DITRICHACEAE

Stems generally less than 2 cm. in height; leaves usually subulate from a broader base (more or less lanceolate in Ceratodon), alar cells not enlarged; peristome typically of 16 slender teeth split into two filiform divisions (no peristone in Bruchia or Pleuridium).

1. Plants minute, rarely collected unless fruiting; stems up to 5 mm. in height; leaves subulate-lanceolate; capsules without peristome.....*Bruchia* and *Pleuridium*
   Plants larger, stems up to 2 cm. in height, rarely more than 5 cm.; leaves lanceolate to subulate; capsules with peristome.....2

2. Stems usually 1-2 cm. long, occasionally up to 5 cm, or more; leaves ovate-lanceolate to narrowly lanceolate; upper leaf cells short-rectangular to more or less quadrate .....*Ceratodon*
   Stems 1-1.5 cm. in length; leaves more or less subulate; upper leaf cells more or less elongate or irregularly quadrate.....3

3. Stems up to 1 cm. in height; leaves secund or more or less crisped when dry, 1-2 mm. long, abruptly linear-subulate from an ovate or oblong clasping base, margins of awn more or less revolute; upper cells irregularly quadrate...*Trematodon*
   Stems up to 1.5 cm. in height; leaves straight or only slightly curved when dry, 2-5 mm. long, linear-subulate from a non-sheathing lanceolate base; upper cells rectangular to linear.....*Ditrichum*

Bruchia

B. Sullivanti Aust.* (Figs. 1-3.) Stems up to 2 mm. in height; upper leaves abruptly subulate-lanceolate from an ovate base, 1-2 mm. long; seta 1-2 mm. long; capsule pear-shaped, 1-1.5 mm. long, neck about the length of spore sac; spores densely spinose, up to 30-40 μ in diameter, maturing June-July. Owen and Putnam Counties.

All figures are copied, with permission, from A. J. Grout, Mosses with Hand-lens and Microscope. (The figures in parentheses refer to Grout, M.H.M.) *Bruchia Sullivanti* (fig. 30). Fig. 1. Gametophytes and sporophytes, x 1. Fig. 2. Same, enlarged. Fig. 3. Spores, enlarged. *Pleuridium subulatum* (fig. 32). Fig. 4. Gametophyte and sporophyte, enlarged. *Ceratodon purpureus* (figs. 36, 37). Fig. 5. Gametophyte and sporophyte, x 2. Fig. 6. Leaves, x 10. Fig. 7. Calyptra, x 10. Fig. 8. Capsule, x 10. Fig. 9. Apical portion of leaf, enlarged. Fig. 10. Basal portion of leaf, enlarged.

Ceratodon

C. purpureus (Hedw.) Brid. (Figs. 5-10.) Leaf margins reflexed to near the apex; seta dark red; capsule dark reddish-brown, grooved when dry, inclined to horizontal. Allen, Carroll, Dearborn, Delaware, Elkhart, Huntington, Jasper, Jefferson,* Kosciusko, Lagrange, Lake, Lawrence, Marshall, Monroe, Montgomery, Newton, Owen, Parke, Porter, Posey, Putnam, St. Joseph, Starke, Steuben, Sullivan, Tippecanoe,* Warren, Wayne,* Wells, White, and Whitley Counties.

Ditrichum

1. Upper leaves 3-5 mm. long, concave, channeled above, basal cells laxly oblong-hexagonal, up to 25 μ wide, 65-85 μ long; seta bright yellowish-orange, 1-4 cm. long; capsule light brown to yellowish, usually inclined and unsymmetric, urn 1-2.5 mm. long, grooved and narrowed at mouth when dry; teeth spinose-papillose; spores warty, 14-18 μ in diameter, maturing in early spring.....*D. pallidum*

   Upper leaves 2-3 mm. long, margins slightly revolute, basal cells linear-rectangular to hexagonal, 10-15 μ wide, 2-5:1; seta reddish-brown, 5-15 mm. long; capsule reddish-brown, usually more or less erect, urn 0.5-1.5 mm. long; commonly not conspicuously grooved or narrowed at mouth when dry; teeth faintly papillose; spores smooth, 10-15 μ in diameter, maturing in autumn.....*D. pusillum*

Ditrichum pallidum (Schreb., Hedw.) Hampe. (Figs. 11, 12.) Carroll, Clark, Dubois, Elkhart, Floyd, Fountain, Franklin, Harrison, Jackson, Jasper, Jefferson, Lagrange, LaPorte, Lawrence, Madison, Marion, Marshall, Martin, Monroe,* Montgomery, Owen, Parke, Perry, Pike, Porter, Posey, Putnam, Ripley,* Spencer, Starke, Steuben, Vigo,* Washington, Wayne,* and White Counties.

Ditrichum pusillum (Hedw.); E. G. Britton, N. Am. Fl. 15[1]:62. 1913. (*D. tortile* Brockm.) (Figs. 13, 14.) Lake, Monroe, Putnam, and Spencer* Counties.

Pleuridium

P. subulatum (Hedw.) Lindb. (*P. alternifolium* (Dicks.; Kaulf.) Rabenh.) (Fig. 4.) Stems up to 5 mm. in height; upper leaves long subulate-acuminate from an ovate or lanceolate base, 3-4 mm. long; seta 0.4-1 mm. long; capsule immersed, ovoid, about 1 mm. long; spores densely papillose, up to 28 μ in diameter, mature in late spring to early summer. Morgan, Owen, and Putnam Counties.

Trematodon

T. longicollis Mx.* Seta yellow; capsule with long neck, urn 1-2 mm. long, neck 2-4 mm. long, curved, with a goiter; spores maturing from April to July. Putnam County (?).

DICRANACEAE

Plants very small to large, stems dichotomously branching, growing in compact mats or cushions; leaves straight and erect to curved and

Ditrichum pallidum (fig. 33). Fig. 11. Gametophyte and sporophyte, x 2¼. Fig. 12. Capsule, x 22½. *Ditrichum pusillum* (fig. 33). Fig. 13. Gametophyte and sporophyte, x 2¼. Fig. 14. Capsule, x 22½. *Dicranella heteromalla* (pl. 11). Fig. 15. Gametophytes and sporophyte, x 1. Fig. 16. Capsule, enlarged. *Dicranella heteromalla*, var. *orthocarpa* (fig. 39). Fig. 17. Capsule and calyptra, x 10. *Dicranella varia* (pl. 13). Fig. 18. Gametophytes and sporophytes, x 1. Fig. 19. Capsules, enlarged.

secund as though all were blown in one direction by the wind, sometimes crispate; peristome of 16 teeth from a low basal membrane, mostly divided more than one-half the way down into narrowly lanceolate or filiform forks.

1. Leaves lanceolate-subulate, alar cells not differentiated.....*Dicranella*
   Leaves broadly to narrowly lanceolate, usually falcate-secund, alar cells strongly differentiated, enlarged, inflated, usually forming a more or less square group of brown or reddish cells.....*Dicranum*

Dicranella

1. Plants light green; leaf margins entire, apices slightly denticulate; costa at base 1/5 of leaf width; seta reddish; capsule oval, more or less nodding and curved, smooth or only slightly wrinkled when dry and empty and mouth not oblique; spores papillose, about 18 μ in diameter, maturing in late autumn.....*D. varia*
   Plants dark green; leaf margins serrulate nearly to base; costa at base 1/3 of leaf width; seta yellowish; capsule ovoid to cylindric; spores smooth, about 15 μ in diameter, maturing from autumn to winter.....2
2. Capsule more or less inclined and unsymmetric, strongly furrowed when dry and empty and mouth oblique.....*D. heteromalla*
   Capsule erect and symmetric or nearly so, shrunken and coarsely furrowed when dry and empty, mouth little or not at all oblique..*D. heteromalla*, var. *orthocarpa*

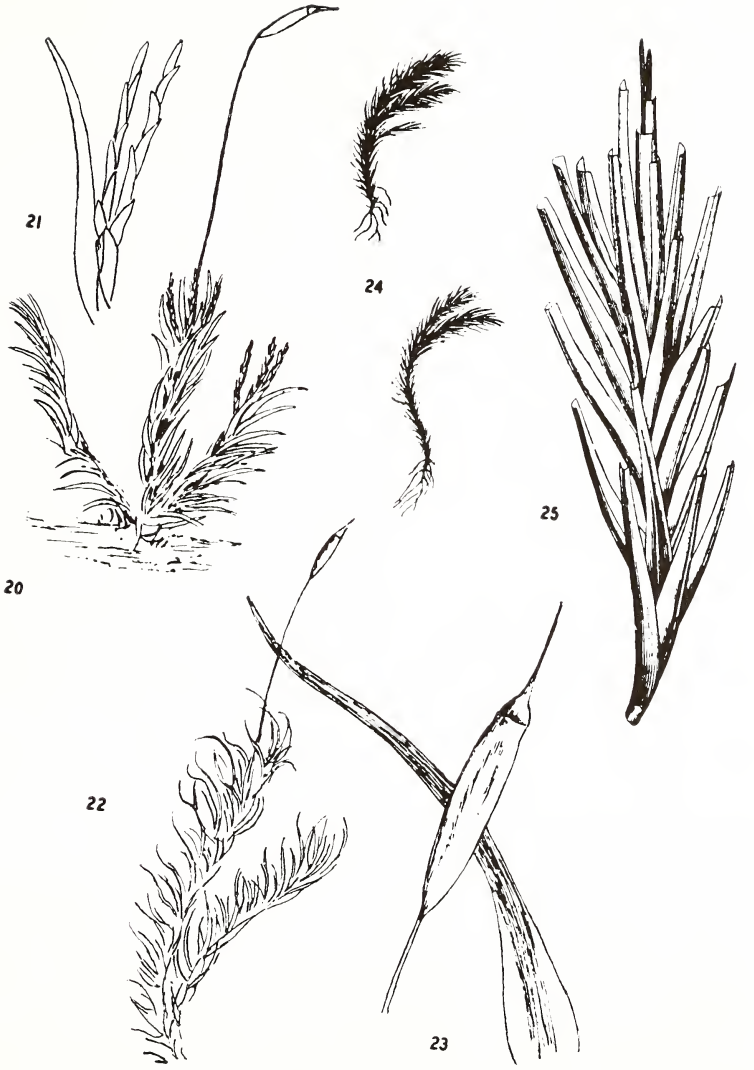
D. heteromalla (Hedw.) Schimp. (Figs. 15, 16.) Brown, Dubois, Floyd, Fountain, Jasper, Jefferson, Lake, Laporte, Marion, Monroe, Montgomery, Owen, Parke, Perry, Pike, Porter, Putnam, Spencer, Steuben, and Wabash Counties.

D. heteromalla (Hedw.) Schimp., var. **orthocarpa** (Hedw.) Paris, Index Bryol. 330. 1895.* (Fig. 17.) Monroe, Putnam, and Tippecanoe Counties.

D. varia (Hedw.) Schimp. (Figs. 18, 19.) Jefferson, Laporte, Monroe, and Putnam Counties.

Dicranum

1. Plants bearing in axils of upper leaves numerous slender flagella covered with minute scale-like ecostate leaves.....*D. flagellare*
   Plants without flagella.....2
2. Leaf cells elongate throughout the blade.....3
   Upper leaf cells short rectangular or more or less quadrate, lower leaf cells elongate.....4
3. Leaves erect-spreading, rarely curved-secund, sometimes undulate; apex broadly acute to obtuse, more or less flat; margin and back of costa slightly or not at all toothed.....*D. Bonjeani*
   Leaves curved-secund, not undulate, strongly serrate above on the long, narrow, more or less tubulose apex.....*D. scoparium*
4. Upper leaf cells short and irregular with angular, somewhat unequally thickened walls; leaves nearly straight when moist, more or less crispate when dry; on dry, sandy soil.....*D. condensatum*
   Upper leaf cells quadrate to short rectangular, rarely more than 2:1; alar cells reaching costa; archegonial plants yellowish-brown or brownish-green; on rock or wood.....5



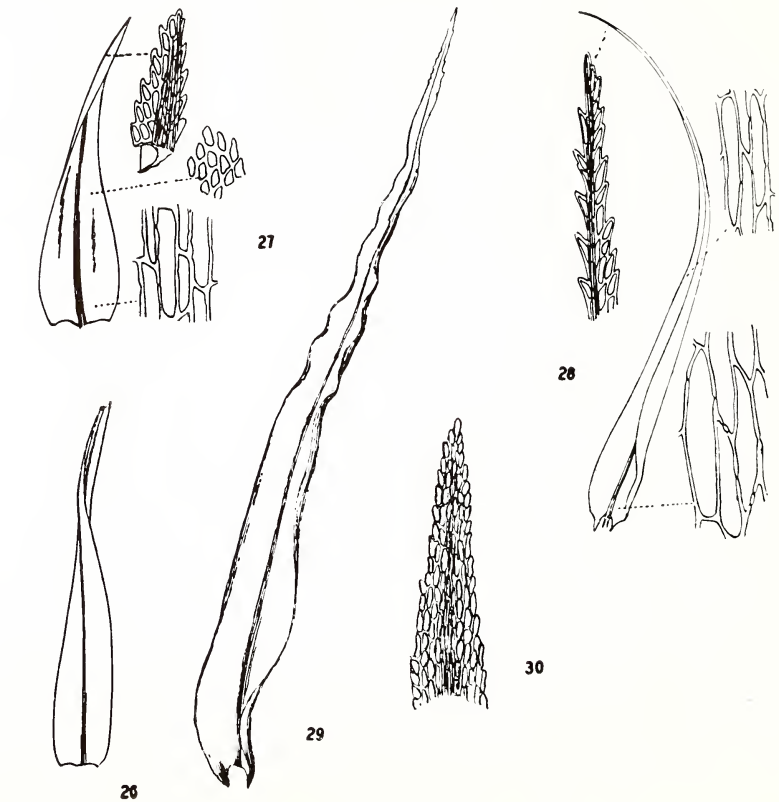
Dicranum flagellare (fig. 46). Fig. 20. Gametophytes, sporophyte, and flagella, x 2¼. Fig. 21. Flagella, x 11½. *Dicranum fulvum* (fig. 46). Fig. 22. Gametophyte and sporophyte, x 2¼. Fig. 23. Capsule and leaf, x 11. *Dicranum fulvum*, var. *viride* (fig. 48). Fig. 24. Sterile plants, x 1½. Fig. 25. Portion of sterile plant from which leaf apices have fallen.

5. Leaves curved and secund; apex present, linear and channeled, usually slightly serrulate and somewhat papillose roughened; on shaded rocks.....*D. fulvum*

Leaves scarcely secund; apex broken off all except the young upper leaves, when present, entire and little or not at all papillose at back; usually growing on wood.....*D. fulvum*, var. *viride*

D. Bonjeani De Not.* (Figs. 29, 30.) Jefferson, Lake, and Noble Counties.

D. condensatum Hedw.* (Figs. 26, 27.) Fountain, Jefferson, Lake, and Putnam Counties.



Dicranum condensatum (fig. 45). Fig. 26. Leaf, x 10. Fig. 27. Leaf, x 10, with apical, median, and basal cells, x 200. *Dicranum scoparium* (fig. 44). Fig. 28. Leaf, x 11, and apical, median, and basal cells, x 225. *Dicranum Bonjeani* (pl. 15). Fig. 29. Leaf showing undulations, enlarged. Fig. 30. Leaf apex, enlarged.

D. flagellare Hedw. (Figs. 20, 21.) Fountain, Lake, Marion, Porter, Putnam, Ripley, Steuben, Wayne,* and Wells Counties.

D. fulvum Hook. (Figs. 22, 23.) Dubois, Fountain, Martin, Monroe,* Montgomery, Parke, Perry, and Putnam Counties.

D. fulvum Hook., var. viride (Sull. & Lesq.) Grout. (Figs. 24, 25.) Monroe, Parke, and Wayne* Counties.

D. scoparium (L.) Hedw. (Fig. 28.) Allen, Carroll, Clark, Crawford, Floyd, Fountain, Jasper, Jefferson, Lagrange, Lake, Laporte, Lawrence, Marshall, Martin, Monroe, Montgomery, Owen, Parke, Perry, Porter, Putnam, Washington, Wayne,* and Wells Counties.

LEUCOBRYACEAE

Plants whitish; leaves with very little chlorophyll, composed almost entirely of costa; capsules unsymmetric, inclined; peristome teeth 16, forked as in Dicranum.

Leucobryum glaucum (Hedw.) Schimp. Mature plants in deep rounded cushions up to 10 cm. or more high; leaves erect-spreading, 3-10 mm. long, upper tubulose portion about 3 times the length of the basal portion. Allen, Carroll, Clark, Crawford, Delaware, Floyd, Fountain, Jasper, Jefferson, Lagrange, Lake, Laporte, Lawrence, Marshall, Martin, Monroe, Montgomery, Noble, Owen, Parke, Perry, Porter, Putnam, Steuben, Warren, Washington, and Wayne* Counties.

A Note on Stemonitis fusca Roth

WILLIAM D. GRAY, University of Pennsylvania

The phenomenon of fairy-ring formation by certain fungi has long been known to mycologists, and numerous workers have reported and figured this type of sporophore arrangement among various agarics. Among the Myxomycetes, however, there have been few reports of fairy-ring formation. Macbride (1899, p. 35) reports such formations as being common to *Physarum cinereum* (Batsch) Pers., stating that the rings are small, measuring but a few inches in diameter. More recently, Poteat (1937) reports the finding of quite large fairy-rings of *P. cinereum*. This author states that he has found rings as large as fifteen feet in diameter. As far as can be determined from available literature, these are the only records of the production of fairy-ring formations by the fruiting bodies of Myxomycetes.

Of the several species of Stemonitis which occur in Indiana, perhaps the two most frequently encountered are *Stemonitis fusca* Roth and *Stemonitis axifera* (Bull.) Macbr. During the spring and summer months, except in exceptionally dry weather, sporangia of one or both of these species may be found in almost any shaded woodlot where moist, decaying twigs and logs occur. In the course of collecting trips throughout the southern part of the state, both species have been observed many times. Fairy-rings, formed by sporangia of *S. fusca*, have been noted

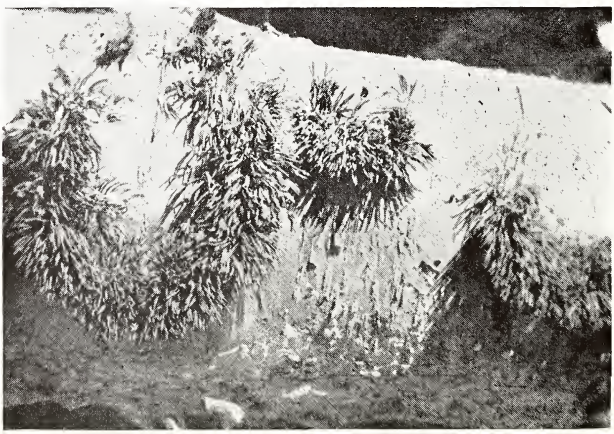


Fig. 1. Sporangia of *Stemonitis fusca* Roth showing two incomplete fairy-rings. Magnification x 2/3.

numerous times, but in no instance were sporangia of *S. axifera* nor any other species of Stemonitis found to be arranged in ring fashion. Such rings are quite small, never approaching the large size reported by Poteat for *P. cinereum;* the largest ring did not exceed three inches,

and the majority were about two inches in diameter. The explanation of such a ring formation is simply that the plasmodium arises at a certain point on the substratum, grows evenly, and creeps at an even rate from the point of origin. When the vegetative phase of the plasmodium is terminated and it enters into the fruiting phase (Seifriz and Russell, 1936), the plasmodium is in the form of a circle; naturally when sporangia are formed, they are arranged thus. In the case of *S. fusca,* fairy-rings were found only on uniformly decayed wood which possessed a fairly even surface. This is prerequisite for ring formation because any obstacle in the path of the advancing plasmodium, such as an uneven place in the surface of the substratum or an area where the texture of the substratum is different, leads to a change in growth rate of the plasmodium at that particular point and hence disrupts the circular arrangement; such rings are shown in Fig. 1.

The fact that *S. fusca* forms rings, whereas no other species of this genus has been observed to do so, leads to the conclusion that such a characteristic is probably a specific one.

Literature Cited

1. Macbride, Thomas H., 1899. The North American species of slime-moulds. Macmillan, New York.

2. Poteat, William L., 1937. A lawn marvel. Science 86:155-156.

3. Seifriz, William and Russell, Mary, 1936. The fruiting of myxomycetes. New Phyt. 35:472-478.

Notes on Indiana Fungi—1937

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Of the species of fungi collected in the vicinity of Bloomington this year several are especially worthy of record for interesting variations in morphology, or for their apparent rarity, or for notable extensions of reported distributions.[1] These notes consider morphological aspects of *Polyporus Berkeleyi* Fr. and *Geastrum triplex* Jung.; the occurrence of *Verticillium albo-atrum* R. & Berth. in connection with wilt of common sumach; and observations on the following species, none of which perhaps has been reported previously for the state: *Marasmius iocephalus* (B. & C.) Penn., of the Atlantic States region; *Glonium clavisporum* Seaver, which has been regarded as a species of the Gulf and Atlantic Coastal Plain flora in its northerly range from Central America; *Orbilia curvatispora* Boud.; and *Hypocrea latizonata* Pk. ex E. & E. on *Cyathus striatus* P.

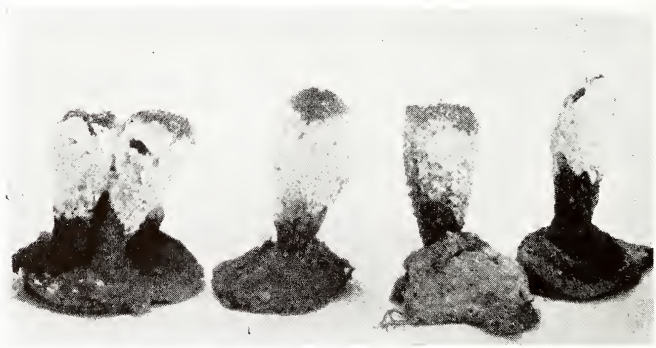

Fig. 1. *Hypocrea latizonata* Pk. ex E. & E. on *Cyathus striatus* P.; x 2.

In general the more common species of fleshy fungi were relatively abundant except during the mid-summer season when expected species of Russula and Lactarius were seen infrequently or not at all.

1. *Marasmius iocephalus* (B. & C.) Penn.[2]

On July 31 ten specimens of this unusual Marasmius, odorous but beautiful, were found attached to unidentifiable decaying leaves in low, wet, wooded ground along Griffy Creek in Monroe County (5788). The

[1] The collection numbers indicated herein are accession numbers in the Mycological Herbarium, Indiana University. Materials have been deposited in other herbaria as follows: Farlow Herbarium, Harvard University, 5775, 5776; Mycological Collections, Bureau of Plant Industry, Washington, D. C., 5775; New York Botanical Gardens, 5775, 5790; University Herbarium, University of Michigan, 5775, 5788.

[2] Specific determination was kindly furnished by Dr. A. H. Smith of the University Herbarium, University of Michigan, wherein specimens of the present collection have been deposited.

fructifications were loosely gregarious; with slender yellowish white stems tomentose above and strigose below; and with caps, measuring up to 3 cm. in diameter, convex, membranous and striate, lilac to violet above and concolorous or paler below in the narrow and rather distant gills. The spores measured 6-7 x 3-3.5 μ, being typical for the species. The caps on drying became bluish gray—the color of iodine crystals as the specific name implies. When fresh caps were crushed between the fingers the odor was suggestive of Skunk Cabbage. Specimens on drying, however, gave a decidedly garlic odor which even persisted in the packets for several days. Aside from the delicate form and attractive color contrast between cap and stem, the most striking feature is the odor which Pennington (North American Flora 9:271. 1915) while recognizing alliaceous odors for other distinct but closely related species, several of which undoubtedly occur in Indiana, describes simply as "strong."

The species was first described by Berkeley and Curtis as *Agaricus iocephalus* on material collected in South Carolina. Pennington (l.c.) gives the distribution as from New York to Alabama and the habitat as upon leaves in woods or swamps. Apparently it has not been reported heretofore from the central states. The present collection, therefore, is of further and special interest for the notable extension of the known range of distribution.

2. *Polyporus Berkeleyi* Fr.

An unusually fine specimen of this giant polypore was received July 6 from Mr. George Bosley, who collected it near Marengo, Crawford County (5783). The species is usually reported as occurring near oak stumps or living oak trees with occasional mention of other species, and in the present instance Mr. Bosley reported that the fructification occurred near the base of a very old, living White Oak. Weir (Phytopathology 3:101. 1913) has noted an association with Beech in Indiana.

When fresh, the specimen measured 52 x 38 cm. and 28 cm. high, exclusive of the irregularly tuberous base which averaged 10 cm. in diameter. The single stalk supported twenty distinct, large pilei, the largest measuring 32 cm. in breadth, and about as many smaller but less distinct fertile imbrications. Basidiospores are typical, being hyaline, obscurely roughened, and subglobose, measuring 8 x 6 μ. Most of the popular treatments of the higher fungi mention fructifications of this species comparable in size, yet these—with the possible exception of Krieger's illustration (Fig. 25, The Mushroom Handbook. 1936. New York)—and the descriptions and illustrations in the technical treatments as well, indicate less massive and more loosely imbricated specimens. Other specimens in our herbarium are less complex, showing but two to five large pilei. However, all are from Monroe County.

A detailed, technical and illustrated account of the rot in oaks due to this fungus is given by Long (Jour. Agr. Research 1:122-125. 1913).

3. *Geastrum triplex* Jung.

Profuse fruiting of the large autumn earth star, *Geastrum triplex* Jung., was observed near Bloomington in October by Miss Wilma Bur-

man, who collected from the fructifications about a maple stump six unexpanded and 32 expanded specimens (5789). The collection is of interest for the fact that, while it is undoubtedly comprised of a single species, one finds among the buttons both globose and acute forms and among opened basidiocarps smooth to fibrilose-sulcate mouths on either indefinite or more or less definite circular areas, which in about half are concolorous with the endoperidium and in the other half paler. These are features of diagnostic value in the recognition of *G. Morganii* Lloyd, *G. Archeri* Berk., and *G. triplex* Jung. Perhaps the majority of the specimens in the present collection, when all features are considered, would be referred to *G. Morganii*, which Lloyd at one time considered distinct from *G. triplex*, and equally as common as that species in the vicinity of Cincinnati. Among more recent American treatments of the genus, there is little agreement on the usage of these names—some students concluding that the three represent distinct species, others placing the *G. Morganii* in the synonymy of *G. Archeri*, and others placing the two in the synonymy of *G. triplex*. The latter contention appears most feasible in view of variations in the present collection when compared with available descriptions of type specimens.

4. *Orbilia curvatispora* Boud.

What appears to be this species as it is recognized by several European students was collected in abundance in Bloomington, on July 27, from the crevices of the bark of a Black Walnut tree which had been dead for one year (5775). The clustered apothecia were concealed in the deeper fissures of the bark where they occurred largely in close relationship with the mycelium of some hymenomycete. The apothecia are somewhat darker than Boudier describes them, being yellowish brown when fresh and drying reddish brown and agreeing more or less with Rehm's conception of the species. They average under 1 mm. in diameter, and they have globular wall-cells 10 to 12 u in diameter and simple septate paraphyses noticeably and typically thickened at the apex; the asci are 35-40 x 3-4 μ and do not blue at the tip with iodine solution; and the ascospores are 7-10 (12) x 1.5 μ, slightly sigmoid or abruptly curved at one end. In comparison with descriptions of European material, the spores are shorter but agree in form, the curvature being pronounced. The species is distinct in size of apothecia and form of spores from *O. rubella* (Pers.) Karst., which occurs on Juglans and other hosts in Europe. *O. coccinella* (Sommf.) ex Fr. and *O. delicatula* Karst., which have been reported as occurring on Juglans in the eastern states, have smaller apothecia and shorter ovoid spores measuring 3-4 x 3 μ.

5. *Glonium clavisporum* Seaver.

Glonium clavisporum Seaver was collected near Bloomington in November, 1936, from bark and wood of a maple log lying in a moderately dense, swampy wood lot (5790). Hysterothecia were not abundant, but the conidial stage *(Sporidesmium stygium* B. & C.) blackened the surface of the log in irregular patches extending altogether about two meters. As to size, both the hysterothecia and the conidia, in specimens taken, are under average but within the limits of the species (Lohman. Bull. Torr. Club 64:61-63. 1937). Asci and ascospores and the hy-

menium, which is yellowish green as seen with a hand lens, are typical. This is a notable extension of the known range of the species, which is tropical and subtropical and heretofore has been considered in North America a component of the Gulf and Atlantic Coastal Plain flora.

In view of present knowledge, this species is separable from *Glonium simulans* Ger., which is widespread in deciduous forest regions of the United States east of the Rocky Mountains and has smaller hysterothecia and ascospores, a paler hymenium, and no known conidial stage. Its occurrence northward in Indiana is doubtful. It may be rare in the southern part of the state. However, at least in certain localities, climatic conditions approximate those of the Coastal Plain and could be favorable to the species perhaps periodically. With respect to climate and the distribution of the species, it is interesting to note that it has been reported recently as occurring in China in the vicinity of Nanking and southward in the coastal provinces of Kiangsu, Chekiang and Fukien, climatic conditions of which approximate those of Alabama and Arkansas.

6. *Hypocrea latizonata* Pk. ex E. & E. on *Cyathus striatus* Pers.

Whereas the fruiting of species of the Hypocreaceae on agarics and polypores is commonplace, such relationship with fructifications of the Gasteromycetes is much to the contrary.

Seemingly very little is known of *Hypocrea latizonata* Pk., a species which Ellis and Everhart (North American Pyrenomycetes, p. 79-80, 1892) ascribe to Peck, based upon a collection of parasitized *Cyathus striatus* Pers. sent by Morgan from Ohio. A scant collection (5776) of this fungus was made in Monroe County early in July, consisting of seven fructifications of what appears to be *C. striatus*, although the habitat of the host is at variance with that recognized for it by students of the Gasteromycetes. The Hypocrea in all respects conforms to the original description, its stromata forming bands on the cups as the specific name implies (Fig. 1). One wonders if perhaps some specific nutritive substance limits the stroma preventing it from entirely enveloping the cup. The stromata are creamy white and closely punctate with minute brownish ostioles. The asci measure 70-80 x 4 μ, the subglobose hyaline sporules 3.5 μ and the individual ascospores 7 x 3 μ. The several cups show various degrees of development of both the host and the parasite.

It appears that a cup is parasitized early in its development, the stroma arising first opposite the base and then developing upward with the elongation of the cup. Possibly the parasite utilizes nutritive tissue which would normally serve the peridioles, for these are mostly lacking or abortive.[3] Only one of the seven cups had developed peridioles, of which five were definitely abortive and two normal in size and color; one of the latter had a few and the other an abundance of hyaline, elliptical basidiospores uniform in size and measuring 17-20 x 7.5 μ.

In all features pertaining to peridiole and basidiospores, the collection conforms to descriptions of *Cyathus striatus* Pers. The cups, however, are nearly smooth within, and they were found loosely scattered

[3] Neither Ellis and Everhart (l. c.) nor Seaver (Mycologia 2:56. 1910. Pl. 20, fig. 9-10) comment on the fertility of the Cyathus in the original collection.

on clayey silt free from any recognizable decaying debris. Lloyd (The Nidulariaceae, p. 18. Cincinnati. 1906), in discussing *C. Schweinitzii*, which is now considered a synonym of *C. striatus*, mentions the occurrence of the species on soil but considers such habit as very rare. White (Bull. Torr. Club 29:262. 1902) describes specimens collected on the ground and on wood in Yucatan with which the present collection agrees in all respects. She refers the material to *C. Montagnei* Tul., a species not yet recognized for temperate North America, emphasizing the faintly striate character of the cups. Most authors, however, consider *C. Montagnei* to have more broadly elliptic spores and its normal habitat in South America to be bark or wood. *C. Poeppigii* Tul., which occurs on damp soil and might be found in this region, has spores twice as large. Since the cups in the present collection are diseased, certain peridial characteristics of specific value thus being obscured or possibly altered, I prefer to record them under *C. striatus* even though the occurrence of the species on soil remains problematical.

Aside from the question of identity of the host, the collection is of particular interest for the apparent infrequency of the parasite. I find in the literature no mention of *Hypocrea latizonata* or any other species of the genus on any species of the Nidulariaceae, other than the original collection referred to. If the Hypocrea is specific to Cyathus and endemic, it is surprising, indeed, that it is not recorded at least by Lloyd, who was interested in both genera. If it occurs only rarely on Cyathus and normally on decaying wood or on hymenomycetous fungi, its specific identity is not evident unless it be *Hypocreopsis tremellicola* (E. & E.) Seaver of *Tremella albida* in Ohio, with cells of the ascospores separated, or a pallid form of *Hypocrea fungicola* Karst., or *H. citrina* (P.) Fr., which is even less likely.

7. *Verticillium albo-atrum* R. & Berth. and wilt of *Rhus glabra* L.

On June 20, in Bloomington, a wilt of *Rhus glabra* L., similar to that reported recently by Fowler (Plant Disease Reporter 21:10. 1937.) for the Smoke Tree, was observed on three shrubs, one having a spread approximately eighteen feet across with one third of the crown diseased. The following week a single wilted specimen was observed in Lawrence County (along a quarry road near Oolitic) and two cases north of Spencer in Owen County. In each instance the wilt appeared to be confined to a single primary branch, and initial wilting had occurred at the time of full flowering or shortly thereafter. From two of the shrubs in Bloomington, *Verticillium albo-atrum* R. & Berth. was consistently isolated from internodes formed in 1936 but not from the new growth. Stems yielding the fungus showed characteristic brownish streaking except in terminal growth of the current year. Streaking was apparent lower than internodes from which isolations were made. Roots were not examined. (5779.)

The disease in Bloomington resulted in complete flagging of wilted leaves, and the flower clusters terminating infected branches did not develop fruits. The twigs remained alive, however, producing in July new foliage, which attained full development and persisted without any outward signs of infection. In contrast to this condition Fowler reports for the Smoke Tree death of infected portions.

Exposure of Fungus Organisms to Ultraviolet Rays

J. Emmert Young, Purdue University

Introduction.—The stimulating effect of the violet portion of the spectrum on growth has been definitely proved for higher green plants. Since fungi lack chlorophyll, their needs as to various wave lengths are not associated with photosynthesis; nevertheless, light in its various forms and intensities is important as an environmental factor. The purpose of this study is to determine the effect of ultraviolet light (which represents very short wave lengths) on the rate of growth, the advancing hyphal tip, and fructification. Results from previous investigations on this phase of light study have been found to be inconclusive on some points. This may be because of numerous factors such as variation in wave-length, intensity of source, nature of any absorbing media interposed, composition of media, age of culture and hydrogen-ion concentration.

Porter and Bockstahler (1929), in their studies concerning the reaction of fungi to various wave lengths, found that ultraviolet inhibited growth and the aerial hyphae collapsed with resultant death. In regard to spore formation, they found sharp inhibition with Cephalothecium but slight acceleration in the case of Colletotrichum. Stevens (1930), Hutchinson and Ashton (1930), and Ramsay and Bailey (1930) also report a stimulation of spore production. Weston (1932) and Smith (1935) report a stimulation of vegetative growth preceded by a previous retardation. The fungicidal action of ultraviolet has been reported by Fulton and Coblentz (1929) in which he killed the spores of twenty-seven miscellaneous species of fungi by comparatively short exposure.

In my study concerning ultraviolet irradiation, I noted particularly the stimulation of aerial mycelium after a slight retardation. The lethal effect on the aerial hyphae and the stimulation of fructification (especially sclerotial formation of *Sclerotia rolfsii*) was also evident.

Investigation.—The present work is concerned primarily with the effect of ultraviolet irradiation on hyphal development and fructification. In all experiments, a Hanover quartz-mercury arc vapor lamp was used, operated on A.C. current. All exposures were made at a distance of 25 cm. from the arc.

Sclerotium rolfsii and *Macrosporium solani* were cultured on potato dextrose agar by means of 5 mm. discs cut from the edge of a normal growing colony. When these colonies had attained a diameter of approximately 2 cm., the lids of the plates were removed and the plates covered aseptically with cellophane. These preparations were then irradiated, three plates of each being exposed 10 sec., 30 sec., 1 min., 5 min. After full strength exposure without filters, the plates were covered with their lids and the colonies incubated at room temperature in darkness. The effect of the irradiation on the hyphal tips was studied one half hour after exposure by cutting out a section of the colony and

placing it in a Van Tiegham cell. The rate of growth was followed and any unusual behavior of the hyphae noted. Increase in diameter of the colonies was recorded after a 10-hour incubation period, and the hyphal tips again studied. The colonies were later studied with respect to effect on fructification.

Data.—The data from this report support the conclusion of Weston (1932) and Smith (1935) concerning stimulation of vegetative growth preceded by a previous period of retardation. *Macrosporium solani*, after ten hours of incubation, showed an average increase of 3 mm. in the control, whereas the plates exposed 5 min. increased only 1 mm., those exposed 1 min. increased 2 mm., and those exposed 10 sec. increased 2.5 mm. *Sclerotium rolfsii* control showed an average increase of 7.5 mm., while the plates exposed 5 min. increased only 1.5 mm., those exposed 1 min. increased 4.5 mm., those exposed 30 sec. increased 6.5 mm., and those exposed 10 sec. showed an average increase of 6.5 mm.

Although the colonies increased in diameter, this increase was due to the hyphae below the surface of the agar, the surface hyphae being killed. This was particularly evident with *Sclerotium rolfsii*, the edge of the colony being distinctly delimited even with a 10 sec. exposure. As shown by the increase in diameter, even the hyphae below the surface of the agar were affected, especially those irradiated 5 min.

An examination of the hyphal tips about one half hour after exposure indicated a tendency toward branching at the tips. Approximately 60% of the tips were forked, many tips were bulbous, and others showed evidence of plasmolysis. Along numerous hyphal strands there appeared small refractive globules. After a 10-hour incubation, tips appeared normal, apex ellipsoidal, and the cytoplasm uniform. In some cases, as many as six branches arose from the same bulbous tip previously mentioned, presenting a broom-like appearance. The rate of growth of numerous hyphal tips after exposure presented no outstanding difference from that of the control.

The effect of irradiation on fructification was outstanding on *Sclerotium rolfsii*. In this organism sclerotial formation follows vegetative development. In the control plates the sclerotial formation was rather uniformly distributed, whereas those exposed showed a tendency toward the formation of sclerotia in the central exposed area, especially those exposed for 5 minutes.

Both *Sclerotium rolfsii* and *Macrosporium solani* showed a decided stimulation of aerial mycelium. After 60 hours of incubation, the colonies of Macrosporium showed this stimulation as a raised cottony circle around the colony originally exposed. This area was considerably darker than a comparative area in the control. *Sclerotium rolfsii* showed a similar white fluffy circle around the original exposed area.

Discussion.—Stimulation of vegetative growth as shown by the raised cottony circle surrounding the area exposed is further substantiated by the branching of the hyphal tips. This retardation of the diameter has been interpreted not only as a checking of the hyphae but also as a branching of the tips already present. Subsequent growth following the initial retardation seems to be greatly accelerated. Previ-

ous workers have suggested that, when growth is retarded, labile products may be stored in the plant and that growth acceleration is brought about immediately following retardation because of this accumulated supply of labile products. Another theory which may be advanced is that certain growth-promoting hormones may accumulate at the bulbous apex of the hyphae and not only cause considerable branching but also accelerated growth of these branched hyphae.

Although the media seem to have a protective influence on the submerged hyphae, increasing the length of exposure was relative in its retarding effectiveness as shown by growth increments. The lethal effect to aerial hyphae was particularly apparent in the case of *Sclerotium rolfsii* colonies, in which even a 10-second exposure sharply delimited the colony, the edges appearing as though trimmed. On the basis of these observations, I feel that the following statements are justified: (1) Fungi are extremely sensitive to ultraviolet irradiation. (2) The hyphal tip is first retarded, then branched, and is finally stimulated in the production of aerial mycelium. (3) Fructification is materially altered, not only in quantity but also in location on the plate, as shown by the ringing effect and massing of sclerotia in the area exposed. (4) The media are partially effective in screening out the rays according to the length of exposure; however, sufficient rays seem to filter through to produce subsequent stimulating effect. (5) Irradiation is lethal to individual aerial hyphae but not to the entire colony.

Effect of Oxygen on Inhibition of Fungi

R. B. Zumstein, Purdue University

The inhibition of one fungus by another in pure culture is a phenomenon that has been found to be of frequent occurrence. The true nature of the cause of inhibition has not, as yet, been definitely determined. Also, there is quite a variation in the amount or extent of influence that one fungus has over another. From various sources there have been isolated certain bacteria that have been found to cause considerable inhibition of certain fungi in pure culture growth in vitro under normal laboratory conditions. My purpose was to determine the effect of an atmosphere of pure oxygen on the inhibition of a fungus plant pathogen colony by a bacterial colony.

Technique.—The organisms used were pure cultures of *Colletotrichum nigrum* and *Bacterium* sp. (F-5.) Equal amounts of Difco potato dextrose agar were poured into six sterile petri plate tops, which were then covered with 8-inch squares of glass. Four of these petri plates were then inoculated at one side with 8-mm. disks of *C. nigrum*, the mycelium side being on the agar. After 72 hours, when the fungus had shown some growth, two of these plates were inoculated with *Bacterium* sp. opposite the fungus and also the remaining two plates, which had been poured and had not previously been inoculated. The three inoculations were made as follows:

(a) *In oxygen*—1 plate with *C. nigrum* only.
1 plate with *B.* sp. only.
1 plate with both cultures on opposite sides.

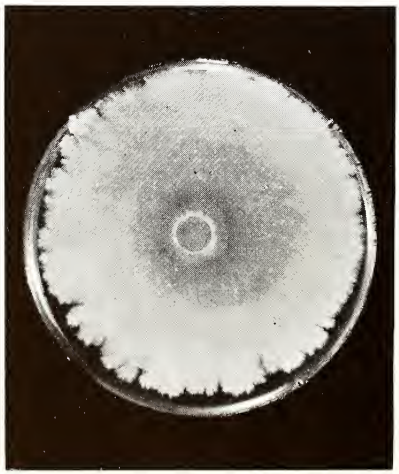

Fig. 1. B. sp. (control).

Fig. 2. B. sp. (in oxygen).

(b) *Control*—same series as in (a), growing under normal conditions.

Three brass gas chambers (Fig. 7) were then sterilized and allowed to cool. The prepared plates (series A) were then each placed over a brass chamber and sealed air-tight with a paraffin-vaseline mixture. The three control plates were also inverted on glass plates. Oxygen was then forced into each gas chamber in turn until all the air had been forced out. A fresh supply of oxygen was forced in daily, sufficient to insure practically a pure atmosphere of oxygen. Measurements

Fig. 3. C. nigrum (control).

Fig. 4. nigrum (in oxygen).

Fig. 5. B. sp. x C. nigrum (control).

Fig. 6. B. sp. x C. nigrum (in oxygen).

of increase in colony diameter were taken every 48 hours for the 14 days that the experiment was carried on.

Observations.—Due to the more rapid growth of the two organisms together in the control, the advancing edge of the *C. nigrum* colony showed as a straight line across the plate—a sign of strong inhibition—48 hours before the same phenomenon appeared with the two colonies together in the oxygen. The advancing edge of a normally developing colony is convex. In the control, there was a clear space 0.8 cm. wide between the two colonies; in the oxygen, the clear space was 1.2 cm. wide.

Conclusion.—1. *Bact.* sp. (control) showed considerably more development than *Bact.* sp. (in oxygen), the former colony reaching the edge of the petri plate by the end of 240 hours and the latter not reaching the edge of the petri plate even after 336 hours (Figs. 1, 2).

2. With *C. nigrum* (control), the colony diameter after 336 hours was 8 cm., while that of *C. nigrum* (in oxygen) was 7.1 cm. at the end of the same period (Figs. 3, 4).

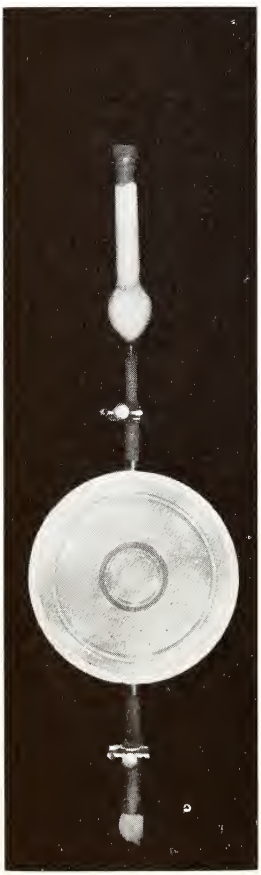

Fig. 7. Gas chamber aparatus.

3. With the two organisms together in the oxygen, both seemed to increase in size proportionately, this continuing throughout the length of the experiment. However, when the size of the colonies at the beginning of the experiment is considered, the increase in size of the bacterial colony was 2.8 cm., while that of *C. nigrum* was only 1.8 cm.

4. With the two organisms together in the control, both colonies seemed to increase in size proportionately; however, if the initial colony size be considered, *B.* sp. showed a growth increment of 3.0 cm., while that of *C. nigrum* was 2.2 cm. (Figs. 5, 6).

5. The difference in width of the open space between the two colonies can be attributed to the reduction in growth of both colonies by the oxygen.

6. With the two organisms growing individually, the graph (Fig. 8) shows that *B.* sp. and *C. nigrum* will develop more rapidly under ordinary laboratory conditions than in an atmosphere of oxygen. The bacterial colony in both cases shows greater development than that of the fungus in air and in oxygen.

7. From the results and observations, it would seem that an atmosphere of oxygen has little effect, if any, on inhibition.

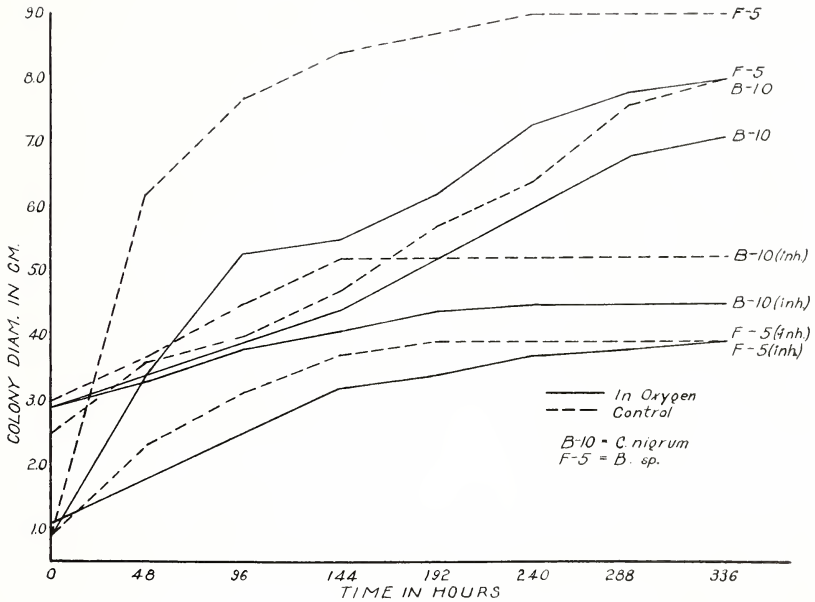
COLONY DIAM. IN CM.
TIME IN HOURS
0
48
96
144
192
240
288
336
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
F-5
F-5
B-10
B-10
B-10 (inh.)
B-10 (inh.)
F-5 (inh.)
F-5 (inh.)
In Oxygen
Control
B-10 = C. nigrum
F-5 = B. sp.

Fig. 8.

Some Acidity Studies in Dunes and Bogs

J. E. Potzger, Butler University

Acidity studies have been a favorite "war horse" of many botanists in the last decade as is evidenced by the large number of papers which have appeared on the subject. One might wonder if the field were not almost exhausted; yet I feel that the present study is somewhat different from most papers dealing with the acidity problem, and it presents features which warrant consideration. Usually study of acidity of habitat is associated with distribution of vegetation; this time we will treat the subject purely as a habitat factor per se and present the extensive comparative phase rather than the intensive applied phase. The extensive collections of peat for fossil pollen work of eleven Indiana bogs presented an excellent opportunity to investigate the acidity factor of the various strata of the peat. The dunes studied are along the shores of Lakes Huron and Michigan, and the similarity in the pH of their soil invited a comparison with dunes of widely separated regions.

Procedure and Methods

During the year 1936-37 our botany department had a number of M.A. candidates working on pollen investigations. This necessitated the hard manual labor of collecting samples of peat at one-foot intervals, and so pH tests could easily be made of the various peat strata, the samples being placed in small vials and securely stoppered. The pH readings were made within a few days after the peat had been collected. The Youden hydrogen-ion apparatus was used. Three readings were made of each foot-level, and the results of the three readings were averaged for the figures shown in the tables. Unfortunately, the peat had to be collected in winter, and the frozen soil prevented taking soil at the surface layer. To facilitate comparison, the profiles of the bogs are plotted against one another according to upper, middle, and lower third, for the actual vertical distance differs too much in the various bogs. (Tables I and II.)

Data on dunes soil are of two sources: one source, records collected by the author on several trips along both shores of the lower peninsula of Michigan and the area about Dunes State Park, Indiana, the other source, data from published records on American and European dunes areas.

Samples of soil were taken of surface layers from the lower beach, just beyond the reach of the waves on a quiet day; from the upper beach, probably never washed by waves except during severe storms; from the environment of grasses; and from wooded older dunes. Lake water was taken at only three stations. (Table III.)

Descriptions of Bogs and Dunes Studied

Bogs.—Most of the bogs studied were within the area covered by the Wisconsin glaciation. As a whole, bogs in Indiana have suffered

much from cultural influences such as fire, grazing, and drainage. Most of them are also senescent, usually in the sedge-meadow stage. Sphagnum is present only in scattered colonies or absent entirely. Some of these bogs are burned over annually. Every one of these depression areas has from one to fourteen feet of marl at the bottom.

Dunes.—Most of the dunes were along the Great Lakes, especially along the shores of Lower Michigan. Included were also dunes from northern Indiana and the lesser sand deposits along the Straits of Mackinac. See Table III for regional location of dunes considered.

Observations

Bogs.—None of the bogs were very acid (Tables I and II), the maximum being 5.06 for the Matthews Bog. All are 6.0 or above in the middle layers. The median pH for the top layer was 6.4, for the middle 6.5, and for the bottom 7.5. Since all of the bogs had marl deposits, the bottom layers range uniformly from neutral to highly alkaline (8.2). We find, however, a progressive increase in alkalinity with increase in depth of peat, viz., 6.4 to 6.6 to 7.5. The variation between the top and the bottom layers fluctuates between one and two pH. Range of fluctuation also varies a little with depth of soil. Range at the top is 5.0 to 7.0, at the center 6.0 to 7.2, and at the bottom 7.8 to 8.2.

Dunes.—The water of Lake Michigan ranges from near neutral to highly alkaline (Table III), and while there is some variation in the acidity of the sand of the lower beach, most readings were near neutral.

TABLE I.—Showing range of pH in strata constituting the upper, middle lower third

Bogs	Range	Depth	Bogs	Range	Depth
Otterbein....."A"	6.18–7.71	1–15	Lake Cicott....."A"	6.09–6.87	1–10
	6.84–7.13	16–30		6.92–7.18	11–20
	7.04–7.14	31–44		6.94–7.9	21–31
Otterbein....."B"	6.48–6.79	1–11	Lake Cicott....."B"	6.72–7.16	1–10
	6.63–7.08	12–22		7.08–7.46	11–20
	6.84–7.06	23–32		7.29–7.63	21–29
Garrett....."A"	5.87–6.11	1–8	Emporia....."A"	5.82–6.24	1–7
	6.14–6.31	9–16		6.38–6.91	8–14
	6.14–7.49	17–23		6.75–7.7	15–21
Garrett....."B"	5.84–6.48	1–8	Emporia....."B"	5.6 –6.6	1–11
	6.02–6.18	9–16		6.5 –6.8	12–22
	5.97–7.49	17–23		6.82–7.97	23–32
Fox Parairie.....	5.7 –6.67	1–14	Bacons Sw.....III	5.25–6.84	1–8
	6.26–6.69	15–28		6.62–6.83	9–15
	6.96–7.63	29–40		6.82–7.73	17–24
Matthews.....	5.06–6.19	1–8	Bacons Sw.....IV	5.95–6.82	1–11
	6.11–6.31	9–16		6.32–6.86	12–24
	6.21–6.91	17–24		6.86–7.69	25–32
Round Lake....."A"	6.09–6.53	1–11	Kokomo....."A"	6.11–6.74	1–11
	6.40–6.52	12–22		5.97–6.75	12–22
	6.43–7.58	23–32		6.96–7.59	23–32
Round Lake....."B"	6.26–6.41	1–4	Kokomo....."B"	5.73–6.31	1–11
	6.26–6.55	5–7		6.04–6.33	12–22
	6.45–6.65	8–10		6.35–7.43	23–32
Cambridge City...."A"	6.62–7.09	1–5	Cambridge City..."C"	6.02–6.65	1–10
	6.5 –7.37	6–10		5.65–6.43	11.19
	7.64–8.21	11–14		6.04–7.85	20–28
Cambridge City...."B"	5.9 –6.82	1–18	Kates Pond.....	6.41–6.72	1–3
	6.58–6.99	19–36		6.16–6.23	4–6
	6.52–7.75	37–53		6.38–6.5	7–9

TABLE II.—Showing pH of strata at top, center and bottom of bogs

Bogs		One foot level	Center	Bottom
Otterbein	"A"	6.18	6.99	7.14
	"B"	6.5	6.92	7.06
Lake Cicott	"A"	6.09	7.09	7.85
	"B"	6.72	7.21	7.63
Garrett	"A"	5.87	6.16	7.49
	"B"	6.48	6.02	7.49
Cranberry Pond	"A"	6.14	6.69	7.7
	"B"	6.23	6.72	7.97
Fox Prairie		5.7	6.52	7.63
Bacons Swamp	III	5.25	6.62	7.41
	IV	5.95	6.77	7.26
Matthews		5.09	6.12	6 91
Round Lake	"A"	6.41	6.35	6.65
	"B"	6.53	6.5	7.58
Kokomo	"A"	6.45	6.5	7.59
	"B"	6.31	6.09	7.43
Cambridge City	"A"	7.09	6.89	8 21
	"B"	6.55	6.65	7 75
	"C"	6.65	6.43	7 85
Kates Pond		6.72	6.16	6.5

TABLE III.—Acidity of soil in various dunes areas

Location	Lake water	Lower Beach	Upper Beach	Among Grasses	Oak-pine dunes	Dunes soil in general
Sturgeon Bay Lake Michigan	7.13	6.5	6.94	6.97	7.04	
Muskegon Lake Michigan	6.86	6.63	6.69	6.94	6.87	
Dunes Park, Indiana Lake Michigan	7.85	6.89	6.29	6.65	6.74	
Mackinaw City Straits of Mackinaw		6.79	6.91			
Rogers, Michigan Lake Huron		6.58	6.65	6.94	6 52	
Blakeney Point, England		7.0			6.8	
Lübeck, Germany		7.0–7.5		7.0		Soils neutral to basic
Carrizo Sands, Texas						Surface 7.18 Subsoil 7.13
Wilcox, Texas						Surface 7.5 Subsoil 7.39
Mount Selman, Texas						Surface 7.29 Subsoil 7.19
North Carolina						4.5 to 5.

This is true for all regions listed in Table III except for the coastal plain of North Carolina. As a whole, I might summarize for all dunes with Onno, (5) "Soils are from neutral to basic, ranging mostly between 6.5 and 7.9 with most readings near neutral." A striking case of acid dunes is the one from the coastal plains of North Carolina where the pH range is between 4.5 and 5.0 (9).

Discussion

Bogs.—Bogs as a rule show acid reactions, at least in the upper layers of peat; but when we speak of bogs, it is essential to take into

consideration the stage of development and influences which had bearing upon the habitat. If a bog is young and sphagnum or other mosses still form a dense surface covering, it will in all probability be acid **(6)**, but the nature of the water will even then have a modifying influence. Water seeping from soil with much soluble calcium, as in regions underlain with limestone or soil rich in limestone debris and shell remains, tends to reduce acidity and favors marl deposits at the bottom. All of the Indiana bogs examined have apparently developed from lakes whose waters were alkaline, for all have a one to fourteen-foot marl deposit at the bottom.

Most of the Indiana bogs suffered extensive surface disturbances such as grazing and repeated fires. The leaching of the ash had without doubt reduced acidity. This is in agreement with the opinion of Ligon **(3)**, who says for the Michigan bogs, "Of mucks which produce crops there are two classes, (1) the alkaline mucks or those having an alkaline reaction caused generally by the ash produced from the burning of mucks of high lime content, and (2) the very strongly acid mucks that are low in lime and have a very high degree of acidity."

Drainage from higher margins of the bogs also carried soluble calcium into the bog proper. One might, thus, justly assume that senescent bogs, where mosses are no longer an important factor in the vegetation and where fires are of frequent occurrence, will gradually decrease in acidity.

That seepage of water from soil rich in calcium bi-carbonate and seepage from ashes after fires tend to lower acidity in these bogs is indicated by increasing alkalinity with increase in depth (Table II). The author **(6)** also pointed this out in the paper on Baxters Bog, a young bog with luxuriant growth of sphagnum. The soils of Indiana where the bogs were studied are Early and Late Wisconsin glaciation depositions, therefore, young, geologically speaking.

Visher **(8)** is of the opinion that erosion in areas covered by Late Wisconsin glaciation is of less magnitude than in the unglaciated areas of Indiana because, "Sufficient time has not yet elapsed since the Late Wisconsin to drain many parts of northern Indiana." These are the areas of "hard water," regions where water softening is an important economic problem. It is, thus, but reasonable to assume that depression areas like bogs would be influenced by water highly charged with calcium bi-carbonate. This factor is stressed by Berquist, et al., **(1)** who say, "In many places throughout the glaciated areas of Michigan, the drift or glacial debris, from the weathering of which the soil has been in large part derived, contains considerable quantities of limestone fragments, and likewise in many places is underlain with bed-rock limestone. The limestone included in the glacial drift is often found as large bowlders or may be present as small nodules and even in the form of finely ground rock flour. It is but natural, therefore, that both surface and ground waters flowing over the calcareous rocks and through the calcareous drift should have a tendency to dissolve out a great deal of the soluble calcium and the water gradually becomes impregnated with calcium bi-carbonate, $Ca(HCO_3)_2$. Since the lime-charged waters flow naturally

into basins or depressions, some of the carbon dioxide (CO_2) is liberated, and the insoluble calcium carbonate ($CaCO_3$) is precipitated and deposited on the floors of swamps, lakes, and stream channels. This deposit is known as marl.

Dunes.—The eastern shore of Lake Michigan is noted for its extensive dunes. In fact, the dunes at Glen Haven, Michigan, are probably some of the most extensive of all inland dunes. As one looks at these immense masses of quartz sand, one may think that dunes soil were acid. Nowhere in the areas studied is this the case. Of course the various locations were more or less under similar influences, but as Table III shows, the dunes of England (7), Germany (5), and Texas (4) had similar pH characteristics. There are no doubt several factors which contribute to the alkalinity of soil in active dunes of the Great Lakes area. The lakes are the source of the sand, and many shells are washed up with the sand. The shell debris is ground up, and the pulverized remains, no doubt, add to the alkalinity of the quartz sand. The limestone strata of the lake bottom contribute to the alkalinity of the water (Table III). There is the possibility that pH of dunes soil will vary with seasons and prevailing weather conditions. Fluctuations are likely to occur because of varying amounts of calcium bicarbonate in lake and seepage water. The older dunes tend to become more acid. This is probably due to decomposition of organic matter and leaching of soluble calcium in the sands. Cain (2) found that slopes in the Great Smoky Mountains became more acid with altitude, and Welch (10) reports that the higher ridges in a limestone region of Monroe County, Indiana, were quite acid. This increasing acidity with increase in altitude in rugged areas is a result of leaching of soluble calcium. The dunes of the coastal plains of North Carolina (9) are no doubt older sands to which no new shell and limestone debris is being added, and thus they will increase in acidity as soluble calcium is leached out.

Summary

1. The paper presents data on acidity of strata of bog soils at one foot intervals and of dunes about the Great Lakes.
2. Comparisons are made with pH of dunes of Texas, North Carolina, England, and Germany.
3. The pH of dunes along the Great Lakes, Texas, England, and Germany is very similar.
4. Limestone substrat, alkaline water, and pulverized shells are suggested as causes of the alkalinity of dunes sand.
5. Leaching of the soluble calcium in the dunes sand is suggested as cause of acidity in older dunes.
6. Indiana bogs examined were all senescent and none were very acid.
7. The bogs studied had from one to fourteen feet of marl deposit at the bottom.
8. Acidity decreases in all with increase in depth.
9. Absence of sphagnum and other mosses and repeated fires are probably the reasons why Indiana bogs are only slightly acid in top and middle strata of the peat.

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Acidity and Moisture in Tree Bark

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Introduction

Moisture is no doubt the one great controlling environmental factor in the deciduous forest area, which is evident from the major vegetational changes which local physiography or micro-climate induce in this region. Potzger (6) found that environmental variation of north- and south-facing slopes controlled the forest types, i.e., oak-hickory on the more xeric south-facing slopes and beech-maple on the mesic north-facing slopes. In a study of the micro-climate of one of these ridges, the same author (6) found that evaporation losses were 60% greater on south- than north-facing slopes.

Working in the ecotone between forest and prairie along the Missouri River, David Costello reports prairie on west-facing slopes and forest on the east-facing slopes. From this he concludes that the major control factor was difference in moisture induced by the prevailing air currents. These reports are of double significance if one considers that the micro-climatic variation here controls the dominant less sensitive vegetation group and that it operates along a sharply defined narrow border line.

The micro-climatic control ripples in ever narrower circles and ever finer degrees of differentiation into the various strata of a vegetation until it reaches the lower cryptogams. Most sensitive plant indicators of variation in moisture are no doubt the epiphytes. In our climatic regions the only epiphytes of any consequence are the mosses.

One finds frequent reference in the literature to presence or absence of epiphytic mosses on tree trunks, and conjectures are made as to the reason for their absence in certain localities, especially in woodlands or parks in or near cities. Now it is evident that in the water relations of these plants one must take two sources of supply into consideration, i.e., the moisture in the air and the moisture of the bark or substratum. In the latter case, the nature of the bark would play a vital part.

Another environmental factor, which has been stressed by various workers in mosses as vital in ecesis and establishment, is the acidity of the substratum. While this factor has received much consideration in soil, little or nothing has been done to study this factor in tree bark.

It is also quite generally recognized or merely assumed that epiphytic mosses are lacking on trees in city parks and woodlands, and the opinion has been expressed frequently that it was due to toxic substances in the atmosphere about a city, viz., fumes, acids, smoke, CO_2, etc. (2, 8, 9, 1). These toxic features are assumed controls, no experimental evidence having been produced to date in support of the reliability of such conclusions.

The environment is always heterogeneous, and thus it becomes a difficult matter to segregate one factor and call it the controlling factor when the control may be an aggregate effect.

An attempt is made in this paper to consider two environmental factors of epiphytic mosses, i.e., moisture and acidity of tree bark and the variation in these factors due to exposure of the trunk and a comparison of the same factors in an undisturbed forest and a characteristic city woodland on the Butler University campus.

Review of the Literature

The sensitiveness of mosses and lichens to impure conditions of urban districts has long been noticed. Haugsja (2), in studying the effect of atmospheric conditions of urban districts on bryophytes and lichens of trees, noticed that they were very sensitive to smoke. Darbishire (quoted by Watson in 2) said that very few lichens within twenty miles of Manchester bore apothecia. According to Watson (2) "even on the Pennines fertile lichens are very scarce since the prevalent winds bring the smoke from industrial districts, though in a few glens sheltered from such winds some lichens such as *Lecanora polytropa, L. varia, Cladonia pyxidata, Biatora graimlosa,* and *Verrucaria viridula* are occasionally found bearing apothecia." Watson (8), likewise, made a study of the bryophytes and lichens of moorlands in England. He said the bryophytes suffered in a similar way as the lichen from impure atmospheric conditions of an industrial district. The atmospheric conditions had a greater effect on the development of corticicolous epiphytes than on the terrestrial cryptogams. He also mentioned that the trees present, which were somewhat dependent on the soil, were correlated in a degree with the epiphytic mosses that were present. "For example, the smooth bark of the beech is the favorite habitat of some species of *Graphis, Arthonia,* etc., though these are not confined to the beech. They have been noted on various trees and have even been found on oaks when they were young and had smooth bark."

Since the lichens were able to reproduce in the areas sheltered from the smoky winds of Manchester, the region in which Darbishire made his study, it seems quite probable that this indicates the presence of greater moisture in that region, and as a result they were able to survive. If smoke had been in the winds, it would have penetrated those sheltered areas just the same as those unprotected. The same drying effect of the prevailing winds would not have been apparent in the sheltered regions, however, and for that reason the moisture content would have been greater.

Bailey (1) attributed the passing of forest mosses to lumbering. He mentioned that "prior to the last decade one could collect within the city limits most of our forest mosses. Now one must go some distance from the city to find them." He thought the smoky atmosphere was well illustrated in the changed conditions of moss growth in the city parks. The forest mosses in his city park had returned in a deep ravine, however. He noticed particularly *Eurhynchium stoloniferum, Hypnum circinale, Aulacomnium androgynum,* and *Neckera Douglassii.* This seemed to him to indicate the fact that climatic conditions were very important for moss growth. It seems that the return of mosses to the sheltered ravine is definitely because of the increased moisture conditions and not because of the protection from the impure atmosphere as he had previously indicated.

Mosses are for the most part indicators of soil acidity. Montgomery (5) tested a number of epiphytic mosses, which were acid as well as the soil on which they grew. He concluded that the moisture supply was a very important factor even when the H-ion concentration was suitable. His range of acidity for the habitats showed that mosses were very tolerant or else not so selective. A study has been made on the distribution or selectivity of mosses in relation to H-ion reaction and bark moisture as well as physiographic location by Wilson (7). Both were considered as limiting factors in addition to the physiographic conditions.

In reference to the position of Pleurococcus and mosses on trees, Kraemer (3) found that bark moisture was the chief factor in their distribution. He showed that the customary belief of "compass mosses" was unfounded. Mosses grow not only on the north side but on all sides of the trunks. He found, in a further examination, that "they grew in the greatest profusion on the shelving side of the trees with a slant of 10° to 20°, since in that position the greatest amount of moisture is received and retained."

Kobendza (4), in a study of bryophytic ecology of the Monts de Sainte Croix, found that mosses occurred more frequently on the trunks and branches of the sycamore than on the same parts of the beeches. This he attributed to the way in which the chinks of the sycamore bark caught and retained moisture and humus.

Thus we find that there is a divided opinion as to the causes for distribution of epiphytic mosses. There are those who believe that the bryophytes are only in rural districts because they cannot withstand the impure atmospheric conditions of the city. The other theory is that cryptogams are absent from cities because of insufficient moisture for growth. Since terrestrial mosses do occur in cities where the epiphytic mosses cannot survive, there must be some truth to the "moisture theory."

Methods

For the acidity tests, bark was collected in late winter both at Fort Harrison and the woods on the Butler campus. One sample from each of the twenty following species was collected from the campus trees in tin boxes:[1] *Aesculus glabra, Fraxinus americana, Carya ovata, Acer negundo, Acer saccharinum, Acer saccharum, Acer rubrum, Celtis occidentalis, Fagus grandifolia, Fraxinus quadrangulata, Tsuga canadensis, Populus deltoides, Quercus borealis maxima, Ulmus americana, Ulmus racemosa, Ulmus fulva, Prunus serotina, Pinus sylvestris, Liriodendron tulipifera, Ostrya virginiana.*

The pH was measured with the Youden H-ion apparatus. The bark was shaved off, covered with water, and the reading taken immediately. Three readings were made from each sample. The active acidity of these readings was averaged and the final pH obtained from that average.

At the Fort Harrison reservation, samples were taken from only eighteen species. Those were:

Ulmus fulva, Ulmus racemosa, Ulmus americana, Acer saccharum, Acer saccharinum, Acer negundo, Carya ovata, Fagus grandifolia, Celtis

[1] Nomenclature is that of Gray's Manual, Seventh Edition.

occidentalis, Salix sp., *Prunus serotina, Fraxinus americana, Quercus borealis maxima, Tilia americana, Platanus occidentalis, Aesculus glabra, Quercus alba.*

The bark was weighed immediately after collecting and then dried for four days in an oven at 100° C. The percentage of moisture present was computed as percentage of dry weight of the bark. An average of the three readings was taken for each of the eight species as shown in the tables. Range of variation is given in a special column.

Observations

The acidity readings of the campus woodland species showed that the bark from the trees was all acid. There was some variation in the acidity according to species (Table I). *Ulmus americana, Acer saccharinum,* and *Liriodendron tulipifera* were the most acid with the pH ranging around 5.2. The least acid were *Populus deltoides, Aesculus glabra,* and *Prunus serotina* with a range of pH, 6.55-6.26.

At the Fort Harrison woods, the acidity readings were made from samples of bark taken separately from the north and south sides of the trees. In all but two cases, the bark from the south side of the trunks tested more acid than that of the north side. This comparison is shown (Table II) with *Prunus serotina, Quercus borealis maxima,* and *Carya ovata* having the most acid bark, while those with least acid bark were *Celtis occidentalis, Acer negundo,* and *Ulmus americana.*

The percentage of moisture absorbed was computed on dry weight of the respective bark. The results obtained from eighteen species are also shown (Table III). These readings were based on only one sample for each species. The percentage of absorption ranged from 13.6% for *Carya ovato* to 22.2% for the *Populus deltoides.* Samples were taken from the north and south sides of each tree instead of one sample as in the collections on the campus. The acidity readings were made as described previously. For these tests, the bark was shaved into a test tube with distilled water; then the readings were made after it had soaked for two hours and not immediately as for the readings of the campus samples.

Moisture Content of the Bark

The samples collected from the campus trees were also used to measure the percentage of moisture absorption. The bark was dried for four days in an electric oven at 100° C. Next, it was weighed and placed into a saturated atmosphere for eight days. After reweighing, the percentage of moisture absorbed was computed on the dry weight of the bark for each species.

In April, a collection was again made from three trees each of the same species at the Fort Harrison woods and the campus for the purpose of determining the amount of moisture present in the bark. Samples were taken from both north and south exposures of the trunks. At the time of collecting there had been a five-day rainless period. At Fort Harrison, samples were also taken from beech and maple located in a protected ravine.

The average moisture present in the bark was derived from samples from three trees of each species, both on the campus and at Fort Har-

rison. In every case, the average moisture was greater on the north side than on the south side. These readings are compared (Table IV). In all but two readings, the moisture on the north side of the trees at Fort Harrison was greater than on the same side of the same species on the Butler campus, and likewise, the south side over the south side. The range in percentage of moisture content for the different species is shown (Table V). There is considerable variation in moisture content for different trees of the same species probably because of location, exposure, and different densities of bark.

Discussion

Plants are an expression of the environment where they grow, and at times these habitat control factors are so sensitive that it is difficult to point with certainty to any one factor and stamp it the controlling factor.

Water is without doubt one of the most important environmental factors. This is especially sensitively expressed in epiphytes where the less stable water content of the atmosphere is the major source of supply. It is a matter of common knowledge that in our region epiphytic mosses are primarily on the north side of trees, seemingly limited by a sharp control. The trees of open city woods and along streets are almost devoid of epiphytic mosses. The question of what factor controls this distribution of epiphytic mosses on trees now arises. Opinions vary. Some think it is difference in moisture; others say it is a difference in acidity. As for trees in cities, the absence of mosses is commonly attributed to toxic conditions caused by smoke and soot in the environs of the city.

The present study concerned itself with two of these environmental factors of epiphytic mosses, viz., moisture and acidity. Since bark of trees is the substratum for these mosses, it was the substrat which was examined for acidity, moisture content, and hygroscopic qualities.

Let us first consider the problem of moisture. This problem involves two phases, i.e., variation in loss of water due to environmental differences and differences in absorptive potentialities of barks. The season when this study had to be carried out prevented atmometer observations on variation in water loss due to exposure. So the characteristics of the bark as water-holding substrata were examined.

TABLE I.—Acidity of Tree Bark for the Butler Campus Species

SPECIES	pH	SPECIES	pH
Aesculus glabra	6.28	Populus deltoides	6.55
Fraxinus americana	6.18	Quercus borealis max	5.61
Carya ovata	6.16	Ulmus americana	5.20
Acer negundo	6.43	Ulmus racemosa	5.44
Acer saccharinum	5.22	Ulmus fulva	5.97
Fagus grandifolia	5.65	Prunus serotina	6.26
Celtis occidentalis	6.14	Acer saccharum	6.16
Acer rubrum	5.58	Pinus sylvestris	6.19
Fraxinus quadrangulata	5.68	Liriodendron tulipifera	5.20
Tsuga canadensis	6.03	Ostrya virginiana	5.82

TABLE II.—Acidity of Bark from Trees at Fort Harrison

Species	Acidity			Acidity	
	South	North		South	North
Ulmus fulva	4.84	5.17	Celtis occidentalis	6.29	6.38
Ulmus racemosa	5.84	6.16	Salix	5.23	6.12
Ulmus americana	6.24	5.77	Prunus serotina	3.80	3.81
Acer saccharum	4.76	5.06	Fraxinus americana	5.44	5.5
Acer saccharinum	5.10	5.20	Quercus borealis max.	4.45	4.405
Acer negundo	6.24	5.87	Tilia americana	5.46	6.06
Carya ovata	4.50	5.10	Platanus occidentalis	4.96	5.36
Fagus grandifolia	4.64	5.22	Aesculus glabra	5.39	....
			Quercus alba	4.62	....

TABLE III.—Percentage of Water Absorbed by Dry Bark of Campus Trees

SPECIES	% absorbed	SPECIES	% absorbed
Aesculus glabra	18.9	Populus deltoides	22.2
Fraxinus americana	18.8	Quercus borealis max.	16.7
Carya ovata	13.6	Ulmus americana	18.2
Acer negundo	22.8	Ulmus fulva	19.0
Acer saccharinum	18.1	Ulmus racemosa	21.6
Fagus grandifolia	18.8	Prunus serotina	16.3
Celtis occidentalis	16.4	Acer saccharum	19.0
Acer rubrum	15.0	Pinus sylvestris	40.1
Fraxinus quadrangulata	19.6	Liriodendron tulip	20.6
Tsuga canadensis	18.8	Ostrya virginiana	22.0

Naturally, the presence of mosses in the protected forest at Fort Harrison and the absence in the open, much-disturbed woodland on the Butler campus invited a comparison which brought out rather interesting features. In bark of all trees (Table IV) but *Ulmus fulva* and *Ulmus racemosa,* the moisture content was greater at Fort Harrison than on the Butler campus. On the north side of trees, the excess ranged from .9% in *Ulmus fulva* to 5.17% in *Fraxinus americana,* while the excess on the south side ranged from .25% in *Aesculus glabra* to 4.3% in *Acer saccharinum* for the trees of the Fort Harrison reservation over those from the Butler campus. There is, thus, a slightly higher difference on north than south exposures. These results become even more significant if we consider that Marion County had an exceptionally wet season with rainfall several inches above normal, clouded skies for most of the spring and winter season, and low temperatures. Only five rainless days had intervened between the last shower and the collecting of the bark. One can readily picture the magnified differences during seasons of high evaporation and low precipitation.

One very significant feature in this study was that the amount of moisture present in bark on the south side of trees at Fort Harrison, where mosses are absent, equalled approximately that of the bark on the north side of trees on the Butler campus. This indicates that moisture, varying with micro-climatic differences, is the control of the absence or the presence of mosses on trees. Kraemer (3) attributed the distribution of epiphytic mosses entirely to the presence of moisture and considers the belief erroneous that mosses grow in general on the north side of trees. He says that, because the shelving side of the tree collects and holds more moisture, the mosses occur there most abundantly whether that be the north or the south side.

Wind action probably accounts for the difference in moisture content of the Fort Harrison and Butler trees. The differences in moisture content of bark on the north and south sides is shown (Table IV). In the city woodland, there is not that protective layer of shrubs or small trees either within or at the edge of the woods so that the wind is allowed a free sweep. Such a drying effect is also apparent in open rural woodlands. J. E. Potzger observed in an open woodland forest in Michigan that mosses were present only at the very base of the roots. Kobendza (4) correlates the presence of mosses and the kinds of epiphytic mosses on trees with the kind and quality of the bark. He holds that moisture was the chief factor involved. In his study of bryophytic ecology of the Monte de Sainte Croix, he found mosses more abundant on sycamores than on the same parts of beeches. He explained that the chinks of the sycamore bark caught and retained moisture and humus, which made the growth of mosses possible.

TABLE IV.—Percentage of Moisture in Bark

SPECIES	Butler Campus Average			Fort Harrison Average			Camparison	
	South	North	Excess N — S	South	North	Excess N — S	Excess N/N	of S/S
Fraxinus americana	8.83%	13.03%	4.20%	10.6%	18.5%	7.90%	5.17	1.77
Aesculus glabra	10.15%	13.86%	3.71%	9.9%	15.8%	5.90%	1.94	0.25
Fagus grandifolia	8.30%	9.77%	1.47%	11.12%	11.64%	0.54%	1.87	2.82
Ulmus racemosa	11.6%	14.2%	2.60%	11.0%	11.10%	0.10%	3.10	....
Ulmus fulva	12.0%	15.4%	3.4%	11.47%	16.3%	4.83%	0.90	....
Ulmus americana	8.93%	12.8%	3.89%	10.35%	14.4%	3.05%	1.60	1.42
Acer saccharum	10.0%	12.86%	2.86%	11.30%	15.73%	4.43%	2.87	1.30
Acer saccharinum	12.0%	12.16%	0.16%	12.93%	16.46%	3.53%	0.93	4.30

TABLE V.—Range in Percentage of Moisture Content

	Butler		Fort Harrison	
	South	North	South	North
Fagus grandifolia	6.9—11.2%	9.3—10.8%	8.2—16.4%	10.02-13.2%
Fraxinus americana	8.4— 9.2%	11.4—14.5%	12.9—15.7%	11.0—22.9%
Aesculus glabra	8.1—12.2%	11.7—15.8%	9.9— 9.9%	12.2—20.5%
Acer Saccharinum	11.6—12.5%	11.3—13.9%	10.7—15.2%	16.0—17.2%
Acer saccharum	9.6—10.5%	10.5—19.5%	9.7—12.8%	14.2—17.2%
Ulmus racemosa	11.3—12.1%	13.5—14.6%	9.9—12.1%	10.9—11.3%
Ulmus americana	7.2—9.9%	8.7—16.5%	10.4—11.3%	10.1—18.7%
Ulmus fulva	12.0—	15.4—	10.3—12.3%	13.2—23.2%

To study additional variations in moisture due to slight micro-climatic differences, two trees, *Fagus grandifolia* and *Acer saccharum*, from a protected ravine at Fort Harrison were included. Not only was the moisture content of the bark on the south side higher than of the trees on the plateau but there was also less difference between the north and south exposures in the ravine.

Apparently there is no doubt that micro-climate is directly related to the presence of mosses. The assumption by certain authors that toxicity is the chief factor in their distribution had been made without sufficient experimental evidence. Darbishire (2) said that fertile lichens, because of the smoke-laden atmosphere, did not appear within twenty

miles of Manchester, England, except in a few sheltered ravines. This, I consider, is not a matter of smoke but the lack of moisture due to the warm, drying prevalent winds. Only in those sheltered ravines was there enough moisture for the epiphytes to exist. It could not have been the smoky atmosphere that prevented their appearance, except in glens, because the smoke would have seeped into the sheltered glens the same as it covered the rest of the area. Bailey (1) likewise attributed the return of mosses to a protected ravine in his city park to the sheltered conditions from the city atmosphere. Both of these workers jump at conclusions and overlook micro-climatic differences affecting moisture.

Now let us examine the hygroscopic characteristics of different barks. There was considerable fluctuation in the range of moisture content (Table V). Since samples were taken from three trees of each species, this variation is expected. Again this shows the effect of micro-climate. If the tree were slightly more protected from the sun and wind, it would in all probability have a greater moisture content. Not only the micro-climatic factor but the depth of the bark fissures would explain this fluctuation. Where the fissures were deeper, evaporation would be less.

The dried bark showed specific differences in degree of absorption (Table III). *Pinus sylvestris* absorbed most; *Carya ovata*, the least. In general, the spongy bark absorbed more than the hard bark. It can readily be seen that the ability to absorb moisture from rain and the atmosphere would have a direct bearing on the growth or presence of epiphytic mosses. If the bark were highly hygroscopic, it would be able to replenish the moisture supply from the humidity of the air. It is known that the relative humidity within a forest is from 5% to 10% greater within than in the open area around it. Therefore, those trees within a protected area would be able to absorb more moisture from the area than those same species in an open woodland.

All of the acidity data bring out the fact, however, that bark of trees as a whole is acid in its reaction as *Prunus serotina*, and Quercus species may even be very acid. Not one of the twenty-three species examined in the present study had bark with alkaline or neutral reaction. This leads one to believe that all bark would probably be suitable substrat for epiphytic mosses from the standpoint of acidity and that the real limiting factor is moisture.

Summary

1. Bark of twenty-three species of trees was tested for acidity, moisture content, and hygroscopic potentialities.

2. Areas studied were a typical undisturbed beech-maple woodland on the Fort Harrison Reservation and a typical open woodland on the Butler University campus.

3. Comparisons are made between results from the two type locations.

4. All bark gave an acid reaction.

5. Range of acidity was pH 3.8 to 6.55.

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6. In the Fort Harrison sampling, north and south sides were compared.

7. As a whole, bark from south sides was slightly more acid than that from the north side.

8. Bark of trees from Butler campus correlated closely in acidity with that of the Fort Harrison trees.

9. Moisture content was greater in the bark of trees on the Fort Harrison Reservation, both on north and south sides, than of trees on the Butler campus.

10. Moisture content of bark from the south side of trees in the Fort Harrison woods was in most cases comparable to that on the north side of the same species on the Butler campus.

11. The hygroscopic potentiality of porous bark was greater than that of compact bark.

12. *Pinus sylvestris* with an absorption of 40.1% was highest and *Carya ovata* with 13.6% was lowest.

13. Ravine protection tended to obliterate the north and south variation of moisture content of trees on uplands.

14. Apparently, moisture is the chief controlling factor in distribution of epiphytic mosses in this locality.

15. Apparently, epiphytic mosses are absent on trees in urban communities and disturbed rural woodlands because of greater desiccating influences.

Thanks is expressed to Dr. J. E. Potzger of Butler University for suggesting the problem and for all supervision and help given while the work was in progress.

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PROGRAM OF THE SECTION ON CHEMISTRY

Chairman: PAUL D. WILKINSON, State Teachers College

1. Substituted acetylenes. G. F. Hennion, University of Notre Dame.
2. The preparation and properties of ethyl amidosulfonate. W. W. Binkley with Ed F. Degering, Purdue University.
3. Correlation and visualization in the teaching of elementary organic chemistry. Ed F. Degering, Purdue University.
4. Objective examinations in chemistry. H. G. DeKay, Purdue University.
5. Objective tests in high school and general chemistry. H. G. DeKay, Purdue University.
6. The preparation and properties of chemiluminescent compounds of the lophine type. Evans W. Cottman, Madison.
7. Photo-stability of suspensoids. R. J. Hartman, D. H. Jung, and L. B. Storms, Indiana University.
8. A detailed study of a reaction used for the preparation of p-alkyl mandelic acids. J. L. Riebsomer, James Irvine, and Robert Andrews, DePauw University.
9. Suggested simplified formulae for the biological amino acids for mnemonic purposes. W. M. Blanchard, DePauw University.

Frank V. Graham, Ball State College, was elected chairman of the Section for 1938.

ABSTRACT

Suggested simplified formulae for the biological amino acids for mnemonic purposes. W. M. BLANCHARD, DePauw University. — A method is outlined for visualizing the relationships of the amino acids. Using glycine, the simplest one, as a basis, it is shown that all except one of the other amino acids may be regarded as theoretical derivatives of this by making substitutions for one of its hydrogen atoms.

Preparation and Properties of Substituted Acetylenes

G. F. Hennion, University of Notre Dame

Introduction

The normal alkyl- and dialkylacetylenes occupy an interesting position among the families of aliphatic hydrocarbons. Beginning with C_5 they are colorless liquids, quite readily prepared and stored. The lower members are gases and, with the exception of acetylene itself, may be condensed by proper refrigeration and (apparently) safely handled. (There is no difficulty in liquefying acetylene, but it is extremely hazardous to do so.) Previous to our investigations very little systematic work had been reported in the literature pertaining to the preparation and reactions of many of these hydrocarbons. Indeed, most of the text and reference works of organic chemistry dismiss these with but a few words or lines at the best. It so happens that many "simple" reactions of the higher acetylenic hydrocarbons remain to be investigated. For example, suitable means for hydration, hydrogenation, oxidation, etc., remain to be reported in many cases. The numerous addition reactions which are possible also promise interesting results. We have reported some of our studies in these connections **(1)**; others are now under active investigation in our laboratory.

If one considers the many homologous series of organic compounds, it is apparent that examples of all of these may be prepared containing a triply bonded pair of carbon atoms, characteristic of acetylene, and containing also various substituents and functional groups. Many such compounds are known, to be sure, but homologous series of these show many vacancies. For such proposed work the monoalkylacetylenes themselves are the logical starting materials. It is evident that two courses of action are possible when one wishes to prepare acetylenic analogs of well-known organic compounds, namely, (a) the desaturation of a suitable paraffinic or olefinic compound to produce a triple linkage where one did not exist previously, and (b) the insertion of a desired alkynyl group into a molecule of fewer carbon atoms. The first method is, in general, not satisfactory. For example, the desaturation of structurally suitable di- and tetrabromides by means of alcoholic alkalies, zinc dust, or other agents, usually gives impure products or low yields or both. The second method is to be preferred whenever possible. It is very fortunate in this connection that acetylenic Grignard reagents are readily prepared. It is only necessary to treat a simple Grignard reagent, such as ethyl magnesium bromide, with an alkylacetylene and warm gently. The ethyl group is replaced by alkynyl as in the following equation.

$$R-C\equiv C-H+C_2H_5-MgBr\rightarrow R-C\equiv C-MgBr+C_2H_6\uparrow$$

The resulting acetylenic Grignard reagent may be used to prepare a wide variety of substances—acetylenic alcohols, ketones, acids, and other hydrocarbons, to mention but a few.

Sodium alkyl acetylides also may be prepared from monoalkylacetylenes by interaction of the acetylene with sodamide in liquid ammonia.

$$R-C\equiv C-H+NaNH_2\rightarrow R-C\equiv C-Na+NH_3$$

Such compounds behave in a manner analogous to the corresponding Grignard reagents and may be used as starting materials for various syntheses.

It is evident then that in the whole field of acetylene chemistry the hydrocarbons themselves occupy a key position. In this sense "acetylene chemistry" includes the study of all organic compounds containing one or more pairs of triply bonded carbon atoms, irrespective of other groups and elements combined in such compounds.

In general the monoalkylacetylenes undergo two fundamental types of reactions:

1. Replacement of acetylenic hydrogen. Typical are reactions in which acetylenic hydrogen is replaced by halogens and by metals. The resulting compounds contain the triple bond intact and may be employed in various syntheses.

2. Addition reactions at the triple bond. These are of two types: catalytic and non-catalytic. Addition of methanol or of carboxylic acids require a catalyst, namely a small amount of the mercuric ion in the presence of a suitable strong acid. On the other hand the halogens and halogen acids add non-catalytically as with the olefins.

The reactions of the dialkylacetylenes are naturally limited to those concerned with the triple bond since acetylenic hydrogen is not contained in these.

It is the purpose of this paper to review the methods now used in our laboratory for the preparation of normal alkyl- and dialkylacetylenes and to cite some of their properties.

Preparation of Monoalkylacetylenes

The best method for preparing monoalkylacetylenes involves the interaction of sodium acetylide and alkyl bromides in liquid ammonia. Well over 500 separate preparations of this general type have been conducted in our laboratory and the results summarized elsewhere (2).

The preparations involve two separate reactions: the preparation of sodium acetylide and its subsequent alkylation. An improvement in the technique of the former reaction has been developed recently whereby 5 to 7 moles of sodium acetylide may be prepared in 2.5 to 3 liters of liquid ammonia in less than 45 minutes. The apparatus used is illustrated in Figure 1 and consists essentially of a special five-liter three-necked flask provided with an efficient stirring mechanism.

In operation this flask is half-filled with anhydrous liquid ammonia and a rapid stream of dry acetylene gas passed in, with rapid agitation. Meanwhile a clean piece of sodium about 4x4x10 cm. is shaved free from oxide coating under dry xylene. The clean sodium is then weighed under dry xylene and a hole punched through one end. A stainless steel wire, about 75 cm. long, is looped through this hole and securely fastened to the sodium. The free end of the wire is led through a piece of

glass tubing, in turn fitted with a rubber stopper suitable for the neck *A*. The assembly is then rapidly transferred to this neck (*A*) and the sodium slowly lowered by means of the wire. In this way the rate of solution of sodium may be controlled readily and an inert atmosphere of ammonia, acetylene, and hydrogen automatically maintained. It is important to maintain a low concentration of dissolved sodium and a

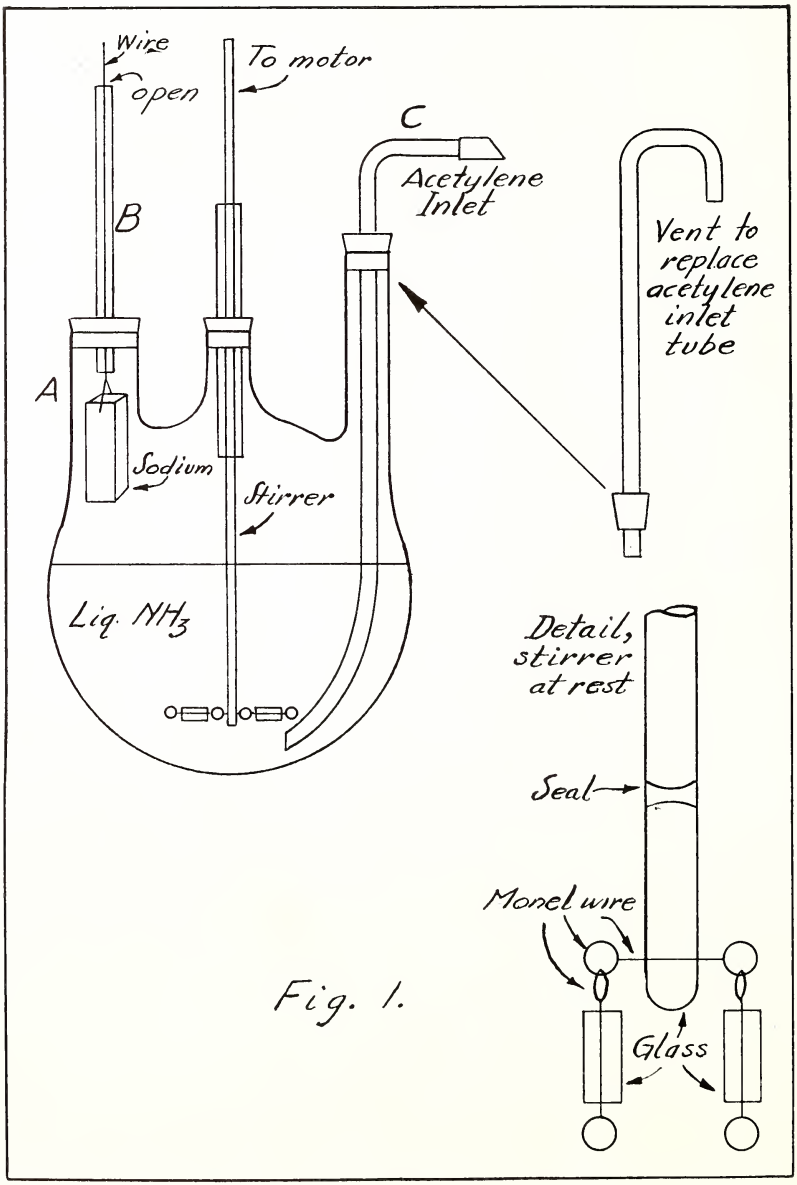

Fig. 1.

high concentration of dissolved acetylene since the latter becomes markedly less soluble as the concentration of sodium increases, consequently slowing tremendously the rate of reaction between sodium and acetylene:

$$Na+H-C\equiv C-H\rightarrow Na-C\equiv C-H+\tfrac{1}{2}H_2$$

By lowering the sodium into the ammonia at such a rate that only the immediate zone in contact with ammonia is colored blue, as much as 3 gram-atoms of sodium may be converted to acetylide in 15 minutes, providing stirring is effective and acetylene passed in at a rapid rate. Obviously the sodium may be replaced when necessary. Indications are about 2 moles of sodium acetylide may be prepared per liter of liquid ammonia at about —34°, the boiling point of the latter. The acetylide remains substantially in solution and appears to be quite free from sodium hydroxide. Ammonia must be added, of course, from time to time, to maintain the volume of the solution.

When the desired amount of acetylide has been prepared the acetylene inlet tube (*C*) is removed and replaced with a glass tube about 50-75 cm. long, to act as a vent for the ammonia vapor. The tube and wire *B* also are removed and replaced with a dropping funnel containing the desired alkylating agent, e.g., n-butyl bromide. The latter is added to the acetylide in a rapid stream of drops and vigorous agitation maintained for 2 to 3 hours after the final addition. The ammonia is then allowed to evaporate until the reaction mixture becomes quite pasty, but not dry. Water or aqueous ammonia (about 300 ml.) is then added with stirring. The product is transferred to a large separatory funnel and the organic layer removed. This is washed with water, 10% hydrochloric acid, water, sodium carbonate solution, and finally with distilled water. Drying over calcium chloride and careful fractional distillation complete the purification. Yields average about 60-70% of the theoretical for butyl and amyl acetylenes and decrease somewhat as the alkyl bromides increase in molecular weight beyond C_5.

Preparation of Dialkylacetylenes

The most widely used methods for preparing dialkylacetylenes involve the alkylation of sodium alkyl acetylides. Since the latter are prepared from monoalkylacetylenes, the following equations indicate a complete synthesis.

$$(1)\quad Na-C\equiv C-H+RX \rightarrow R-C\equiv C-H+NaX$$
$$(2)\quad R-C\equiv C-H+NaNH_2\rightarrow R-C\equiv C-Na+NH_3$$
$$(3)\quad R-C\equiv C-Na+RX \rightarrow R-C\equiv C-R+NaX$$

Such reactions are carried out in liquid ammonia with satisfactory results **(2)**, except that the time consumed in conducting these separately is considerable. Recently we have observed that these reactions may be conducted *simultaneously* in liquid ammonia, by simply mixing the three required reagents in suitable proportions **(3)**. Since intermediate products are not isolated or purified in any way, a considerable saving of time is effected.

In a typical synthesis 1.2 moles of sodium acetylide is prepared in one liter of liquid ammonia, as previously described. At the same

time 1.5 moles of sodamide is prepared in a separate container from 1.5 gram-atoms of sodium and 750 ml. of liquid ammonia, using hydrated ferric nitrate as a catalyst (4). The sodium acetylide and sodamide are mixed and 2 moles of n-butyl bromide added with vigorous agitation. After 2 to 3 hours of stirring, water is added and the dialkylacetylene purified in the manner described for monoalkylacetylenes.

These rapid preparations constitute a new technique for obtaining long carbon chains and are therefore of considerable academic interest.

Physical Properties of Substituted Acetylenes

Reliable physical data for the acetylenic hydrocarbons are meager. This is probably due to the fact that few investigators have prepared such compounds in a high degree of purity. It is of interest to note that in the disubstituted acetylenes we have unsaturated compounds in which there are no complications due to cis-trans isomerism.

TABLE I.—Physical Properties of Normal Acetylenic Hydrocarbons

Formulae		Boiling Points			Densities		Refractive Indices	
R—C≡C—R′		Mm. of Hg		Ref.				
R	R′	760	50		d_t	Ref.	$_nD_t$	Ref.
H	H	—83.6		5	0.6208_{bp}	5		
CH_3	H	—23.3		5	0.6698_{bp}	5		
C_2H_5	H	8.6		5	0.6682_{bp}	5		
CH_3	CH_3	27.2		6	0.688_{25}	6	1.3893_{25}	6
C_3H_7	H	39.7		5	0.6718_{bp}	5	1.388_{17}	7
C_2H_5	CH_3	55.5		8	0.7127_{17}	8	1.4045_{17}	8
C_4H_9	H	71.0	4.7	9	0.721_{17}	7	1.402_{19}	7
C_3H_7	CH_3	83.8		10	0.7352_{15}	10		
C_2H_5	C_2H_5	82	11.1	9	0.7263_{25}	9	1.4112_{25}	9
C_5H_{11}	H	99.8	26.5	9	0.7288_{25}	11	1.4135_{13}	12
C_4H_9	CH_3	112.0	39.5	9	0.745_{25}	9	1.4220_{25}	9
C_3H_7	C_2H_5	106–7		7	0.7337_{25}	13	1.415_{25}	13
C_6H_{13}	H	126.0	50.8	9	0.743_{25}	9	1.4140_{25}	9
C_5H_{11}	CH_3	137.2	60.2	9	0.761_{25}	9	1.4285_{25}	9
C_4H_9	C_2H_5	133	56.7	9	0.7501_{25}	9	1.4230_{25}	9
C_3H_7	C_3H_7	131	55	9	0.7474_{25}	9	1.4225_{25}	9

In Table I we present the boiling points, densities, and indices of refraction of the isomeric straight-chain acetylenes to C_8 inclusive, in so far as the data are available. There is sufficient information to permit of certain interesting generalizations. In any group of isomeric straight-chain acetylenes the following are true.

1. The monosubstituted acetylene has the lowest boiling point, density, and index of refraction.

2. The acetylene having a terminal methyl group adjacent to the triple bond has the highest boiling point, density, and index of refraction.

3. Within the disubstituted acetylenes the most symmetrical compound has the lowest boiling point, density, and index of refraction.

These relationships are particularly manifest with the four isomeric octynes where boiling points at two pressures and densities and indices of refraction both at 25°, are available.

Summary

The preparation of some substituted acetylenes from sodium acetylide in liquid ammonia has been described. A new technique for preparing sodium acetylide has been given. The physical properties of a number of alkyl and dialkylacetylenes have been tabulated and certain generalizations established.

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The Preparation and Properties of Ethyl Amidosulfonate

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Ephraim and Lasocky (1) reported the preparation of methyl amidosulfonate from methyl iodide and silver amidosulfonate in 1911. No further investigation of this compound or its homologues has since been reported. The present study was undertaken with the hope of obtaining ethyl amidosulfonate and then studying its properties.

Preparation of Amidosulfonic Acid.—Amidosulfonic acid may be obtained by saturating an aqueous solution of hydroxylamine hydrochloride, or better hydroxylamine sulfate, with sulfur dioxide. A more economic course, however, was pursued. Sodium amidosulfonate was prepared by the reduction of sodium nitrite with sulfur dioxide in the presence of sodium carbonate. The acid was then liberated from the sodium salt with sulfuric acid (2). Well-formed crystals of this colorless acid were easily obtained. The acid has a sharp sour taste. The yields were 50 to 60% (Table I a).

Preparation of Silver Amidosulfonate.—Although Divers and Haga (2) did not disclose their method for preparing silver amidosulfonate, they recommended obtaining it from amidosulfonic acid. It was obtained readily from amidosulfonic acid and silver carbonate, according to the following equation:

$$2HO \cdot SO_2 \cdot NH_2 + Ag_2CO_3 \rightarrow 2AgO \cdot SO_2 \cdot NH_2 + CO_2 + H_2O$$

Excellent yields of colorless, striated prisms of silver amidosulfonate were obtained (Table I, b).

Preparation of Ethyl Amidosulfonate.—Finely divided silver amidosulfonate (10 g.) was placed in a large test tube equipped with a mechanical stirrer. A solution of 4 ml. of ethyl iodide dissolved in 25 ml. of ethyl ether was poured into the test tube, and the stirring begun. The reaction started at once as evidenced by the formation of yellow silver iodide. The agitation was continued for 24 hours and the ether removed by decantation. This residue was extracted with two 25 ml. portions of hot absolute ethyl alcohol. The alcohol was removed by distillation, and a light yellow solid with a sweet odor remained. The last traces of ethyl alcohol, color, and odor were removed from the residue by washing with a few milliliters of ethyl ether on a porus plate. The presence of carbon, hydrogen, sulfur, and nitrogen was established in the usual manner and sulfur was determined quantitatively (Table I, c). Ethyl amidosulfonate is a crystalline solid which decomposes without evidencing a definite melting point. It begins to sweat between 140° and 150°C. and to decompose with foaming and charring at 209°C. The yields were 2 to 3 g.

TABLE I.—Analytical Results

	Theoretical	Obtained
a. Molecular weight of amidosulfonic acid by neutral equivalent	97 g.	96.7 g. ± 0.2
b. Silver in silver amidosulfonate	52.7%	52.9% ± 0.1
c. Sulfur in ethyl amidosulfonate	25.6%	25.1% ± 0.4

Summary.—Ethyl amidosulfonate may be prepared as a crystalline solid from ethyl iodide and silver amidosulfonate.

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The Preparation and Properties of Chemiluminescent Compounds of the Lophine Type

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The Cottman Laboratory of Photochemical Research, Madison

Introduction

Lophine was prepared by Radziszewski, using the two following methods:

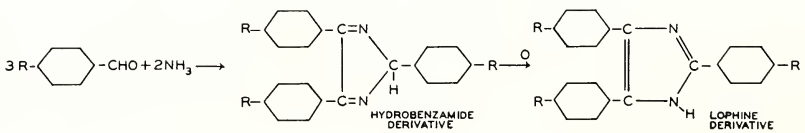
First Method. In 1877 he prepared lophine by treating benzaldehyde with an excess of ammonium hydroxide, and subsequently oxidizing the hydrobenzamide so formed, with atmospheric oxygen.[1]

Second Method. In 1882 he prepared lophine my ammonating equivalent amounts of benzil and benzaldehyde with dry ammonia gas in alcoholic solution at a temperature of 45°-50°.[2] He was the first to report on the chemiluminescent properties of lophine when oxidized in alcoholic potash solution.

Since little or nothing has been done along this line since 1882, the present writers have repeated Radziszewski's work, have attempted to obtain the optimum conditions for luminescence of lophine, attempted the preparation of a number of lophine derivatives, and studied the spectra of those lophine derivatives which show a marked degree of chemiluminescence. The writers are greatly indebted to the Eli Lilly Research Laboratories of Indianapolis, in which the analytical and spectrometric work was done.

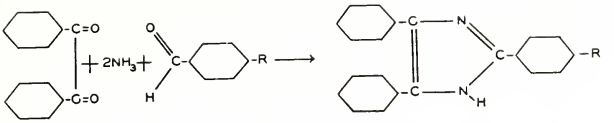
Discussion

Preparation of Lophine Derivatives.—Following the two methods of Radziszewski, outlined above, it was reasoned that if substituted benzaldehyde derivatives were used in place of benzaldehyde itself, the corresponding lophine derivatives would be prepared. For example, if the first method were used, a trisubstituted lophine derivative would result:



If Radziszewski's second method were used, it was reasoned that a monosubstituted lophine derivative should result from using a substituted benzaldehyde derivative, the substitution occurring in the 2-position of the imidazole ring:

[1] Radziszewski, 1877. Ber. **10**:70-5.
[2] Radziszewski, 1882. Ber. **15**:1493-5.



The following benzaldehyde derivatives were used in attempting to prepare the monosubstituted and trisubstituted lophine derivatives and the hydrobenzamide derivatives:

1. Piperonal (Eastman Kodak Co.).
2. *m*—Nitrobenzaldehyde (C. A. F. Kahlbaum Chemischefabrik, Adlershof bei Berlin).
3. *p*—Dimethylaminobenzaldehyde (Eastman Kodak Co).
4. *p*—Hydroxybenzaldehyde.
5. Anisaldehyde (Eastman Kodak Co.).
6. *o*—Nitrobenzaldehyde (Dr. Theodor Schuchardt Görlitz).
7. Salicylaldehyde (Eastman Kodak Co.).
8. Resorcylaldehyde (Eastman Kodak Co.).
9. Veratraldehyde (Eastman Kodak Co.).
10. Vanillin (Eastman Kodak Co.).

The first method, described above, was used in preparing all hydrobenzamide derivatives and trisubstituted lophine derivatives. The second method was used in preparing all monosubstituted lophine derivatives. All the benzaldehyde derivatives were reactive toward aqueous ammonia except the *p*—dimethylaminobenzaldehyde. In general, the reactions paralleled those for the preparation of the normal lophine. A few of the compounds were gummy, and all attempts to purify them were unsuccessful. The nitrogen analyses of these compounds were valueless, but it was deemed worthwhile to include these compounds in the discussion because of their luminescent properties.

While definite proof is lacking, the evidence seems to point to the fact that a number of the desired lophine and hydrobenzamide derivatives were actually prepared, whereas some were doubtful. This evidence is as follows:

1. The method of preparation was similar to that of preparing lophine itself.

2. The physical appearances of the reactions were similar in many cases to those involved in normal lophine preparation.

3. Many of the nitrogen analyses checked fairly closely with the theoretical values.

4. Most of the compounds produced a chemiluminescence, similar to that of normal lophine, upon oxidation.

In view of the fact that complete proof of structure is lacking, the writers wish to be understood that the names used in this article for these compounds are employed for convenience and are provisional.

Optimum Conditions for the Luminescence of Lophine.—For luminescence of lophine to take place, the solution must be alkaline. Either sodium hydroxide or potassium hydroxide should be used. The solvent most generally used is ethyl alcohol, but methyl alcohol, acetone, dioxan, and several other solvents may be used successfully. To complete the

conditions, a proper oxidizing agent, together with a peroxide (usually hydrogen peroxide), must be used. The choice of oxidizing agent is an important point. Out of about fifty such reagents tried, the four following ones were found to be most successful: sodium hypochlorite, potassium ferricyanide, perchromic acid, haemoglobin. As the sodium hypochlorite was most extensively used in these researches, full directions for its preparation and use will be given in the Experimental Part.

Chemiluminescent Properties of the Derivatives.—Numbers I, II, V, VIII, IX and X, described in the Experimental Part, give no light and are assumed to be hydrobenzamide derivatives. Numbers IV, VII and XII are assumed to be monosubstituted lophine derivatives, and numbers III, VI and XI, trisubstituted lophine derivatives. The luminescent properties of the lophine derivatives will be described individually in the Experimental Part.

The spectra of lophine and eight of its most luminescent derivatives were studied with a Hilger spectroscope. All the luminescent derivatives give a pale yellowish light similar to that of normal lophine. The yellow color appears deeper in the more intense lights. Examined through the spectroscope, the spectra are found to be continuous, and lying approximately between 4800 and 6000 Angstrom units. The point of maximum intensity is about 5300 Angstrom units. The width of the visible band, of course, increases or decreases according to the intensity of the light. Since the intensity of the light is small, it was found necessary to strengthen it in order to take the spectroscopic readings. The device used for this purpose is described in the Experimental Part. An unsuccessful attempt was made to photograph the lophine spectrum, exposures up to three hours being made with a supersensitive panchromatic film.

Experimental Part

A. Preparation of the Derivatives

I. *3, 4, 3′, 4′, 3″, 4″-tris (methylenedioxy) hydrobenzamide:* Pulverized piperonal is set aside in a stoppered flask with an excess of ammonium hydroxide. The derivative forms in about three days as a whitish crystalline cake. It is purified by rinsing several times on the filter with hot alcohol, in which it is slightly soluble. The yield is small.

II. *m, m′, m″-tris (nitro) hydrobenzamide: M*-nitrobenzaldehyde is set aside in a stoppered flask with an excess of ammonium hydroxide for three days. The derivative forms as a very hard light brown cake. The brown color is dissolved out with hot alcohol, leaving the purified derivative as a flesh-colored residue.

III. *2, 4, 5-tris-m-nitrophenylimidazole:* No. II is fused in air and heated with constant stirring. It cools to a very dark brown brittle mass which is moderately soluble in hot alcohol. It is purified by recrystallization from hot alcohol. It gives rather poor luminescence of short duration.

IV. *2-m-nitrophenyl-4, 5-diphenylimidazole:* Equivalent amounts of benzil and *m*-nitrobenzaldehyde in alcoholic solution are saturated with

dry ammonia gas at 45°-50°. The derivative separates out as a bright yellow precipitate. It is purified by recrystallization from hot alcohol. It gives a fair degree of luminescence.

V. *p, p', p"-tris (methoxy) hydrobenzamide:* Anisaldehyde is set aside in a stoppered flask with an excess of ammonium hydroxide for three days. A brownish crystalline cake forms, and is steeped in hot alcohol several times to remove the impurities. The final residue is nearly white.

VI. *2, 4, 5-tris-p-methoxyphenylimidazole:* No. V is fused and heated in air with constant stirring. It fuses to an orange colored liquid which hardens, upon cooling, to a brittle vitreous mass. All attempts to get this into a crystalline form failed. However, a nitrogen analysis was made of the substance, with surprisingly close results. The chemiluminescent properties of this compound are exceptionally good. The light is of about the same intensity as that of lophine, but of longer duration. Of course, no melting point was obtainable.

VII. *2-p-methoxyphenyl-4, 5-diphenylimidazole:* Equivalent amounts of benzil and anisaldehyde in alcoholic solution are saturated with dry ammonia gas at 45°-50°. A white precipitate settles out and is filtered off. Upon standing, yellow crystals separate out from the filtrate. They are purified by washing with ether and recrystallizing from hot alcohol. This compound gives a yellow light noticeably brighter than that of lophine, but of shorter duration.

VIII. *o, o', o"-tris (hydroxy) hydrobenzamide:* An excess of ammonium hydroxide is added to salicylaldehyde and an immediate yellow precipitate forms. It darkens and hardens upon standing. It is dissolved in hot alcohol from which it separates very slowly into yellow crystals and an oil. The crystals are washed with ether to remove the oil.

IX. *2, 4, 2', 4', 2", 4"-tris (dihydroxy) hydrobenzamide:* An excess of ammonium hydroxide, added to resorcylaldehyde, produces a very dark red solution. After standing several days, this is dried on a water bath, forming a red powder, coated with black. It is somewhat soluble both in alcohol and water. The red powder is purified by washing alternately with water and alcohol. The substance decomposes before reaching its melting point.

X. *3, 4, 3', 4', 3", 4"-tris (dimethoxy) hydrobenzamide:* Veratraldehyde is set aside in a stoppered flask with an excess of ammonium hydroxide for three days. It swells up forming a flocculent white precipitate which fills the flask. This is purified by recrystallizing from hot acetone.

XI. *2, 4, 5-tris (3, 4-dimethoxyphenyl) imidazole:* No. X is fused and heated in air. It cools to form a very dark brittle substance, which is very soluble in alcohol. It is precipitated from alcoholic solution by water containing ethylene glycol. The final product is grayish brown. It gives a good luminescence.

XII. *2 (3, 4-dimethoxyphenyl)-4, 5-diphenylimidazole:* Equivalent amounts of benzil and veratraldehyde in alcoholic solution are saturated with dry ammonia gas at 45°-50°. The substance behaves similarly to the preparation of No. VII. First a white precipitate separates.

This is filtered off. Upon standing, yellow crystals separate from the filtrate. These are purified by washing with ether and recrystallizing from hot alcohol. This compound gives a luminescence slightly more intense than normal lophine.

TABLE I.—Numerical Data on the Derivatives

No. *	Probable empirical formula	Melting point	Nitrogen anal. calc.	Nitrogen analysis found
I	$C_{24}H_{18}N_2O_6$	94°	6.51%	6.21%, 6.14%
II	$C_{21}H_{15}N_5O_6$	140°	16.16%	15.88%, 16.01%
III	$C_{21}H_{13}N_5O_6$	126°	16.24%	16.05%, 16.09%
IV	$C_{21}H_{15}N_3O_2$	....	12.31%	12.21%, 12.20%
V	$C_{24}H_{24}N_2O_3$	127°	7.21%	7.14%, 7.18%
VI	$C_{24}H_{22}N_2O_3$	....	7.23%	7.16%, 7.28%
VII	$C_{22}H_{18}N_2O$	202°	8.59%	8.38%, 8.45%
VIII	$C_{21}H_{18}N_2O_3$	136°	8.09%	8.03%, 8.12%
IX	$C_{21}H_{18}N_2O_6$	Decomposes	7.10%	6.82%, 6.95%
X	$C_{27}H_{30}N_2O_6$	132°	5.85%	5.77%, 5.65%
XI	$C_{27}H_{28}N_2O_6$	91°–95°	5.88%	5.78%, 5.80%
XII	$C_{23}H_{20}N_2O_2$	....	7.86%	8.00%, 8.04%

* The names of these compounds are given in the text.

An attempt was made to prepare the following compounds by the methods outlined above:

a. 2, 4, 5-tris (3, 4-methylenedioxyphenyl) imidazole from piperonal.
b. 2 (3, 4-methylenedioxyphenyl) 4, 5-diphenylimidazole from piperonal.
c. 2-*p*-dimethylaminophenyl-4, 5-diphenylimidazole from *p*-dimethylaminobenzaldehyde.
d. 2-*o*-nitrophenyl-4, 5-diphenylimidazole from *o*-nitrobenzaldehyde.
e. 2-o-hydroxyphenyl-4, 5-diphenylimidazole from salicylaldehyde.

These substances could not be purified sufficiently to give satisfactory analyses. However, they were all strongly chemiluminescent, which would seem to point to the fact that the lophine derivatives were probably prepared to some extent.

All attempts to ammonate *p*-hydroxybenzaldehyde and vanillin proved futile. Likewise, attempts to prepare the following compounds yielded no results, either with respect to analysis or to chemiluminescence:

a. *p*, *p'*, *p''*-tris (dimethylamino) hydrobenzamide by ammonation of *p*-dimethylaminobenzaldehyde.
b. *o*, *o'*, *o''*-tris (nitro) hydrobenzamide by ammonation of *o*-nitrobenzaldehyde.
c. 2, 4, 5-tris-*o*-nitrophenylimidazole by atmospheric oxidation of the supposed hydrobenzamide derivative.
d. 2, 4, 5-tris-*o*-hydroxyphenylimidazole by atmospheric oxidation of derivative No. VIII.
e. 2, 4, 5-tris (2, 4-dihydroxyphenyl) imidazole by atmospheric oxidation of derivative No. IX.
f. 2 (2, 4-dihydroxyphenyl)-4, 5-diphenylimidazole by ammonation of resorcylaldehyde and benzil.

B. Optimum Conditions for Luminescence of Lophine

Three solutions are prepared:

Solution 1 (Lophine solution): To a saturated alcoholic solution of lophine, an equal volume of alcohol is added.

Solution 2: 1 part 3% hydrogen peroxide is added to 7 parts water.

Solution 3: 5% sodium hypochlorite*.....25cc.
Sodium hydroxide .....10 gm.
Water .....175cc.

For each trial, 2cc. of Solution 2 is added to 4cc. of Solution 1. The room is then darkened and 2 cc. of Solution 3 is added to the mixture. An excellent luminescence results.

C. Device for Intensifying the Light

A glass tube, two feet long and one-half inch outside diameter, was sealed at both ends. Three small side entrance tubes were attached just back of the front end. An exit tube was attached at the rear end. The entire tube was silvered on the outside, except for a small window in the front end. This window was placed against the slit of the spectroscope with the axis of the tube in direct line with that of the collimating tube of the spectroscope. The three entrance tubes were connected to separate reservoirs containing the the various required solutions. Lophine solution was allowed to enter through one of the tubes, hydrogen peroxide solution through the second, and the mixture of potassium hydroxide and sodium hypochlorite through the third. The instructions for making up these solutions have already been given. As the solutions mix, luminescence occurs within the tube. This is intensified by the reflections and by the length of the tube.

Summary

1. A number of chemiluminescent substances were prepared through ammonation of benzaldehyde derivatives.

2. The methods used in preparing these substances followed those used in preparing hydrobenzamide and lophine.

3. Incomplete evidence indicates that a number of hydrobenzamide and lophine derivatives were prepared from the corresponding benzaldehyde derivatives.

4. The spectra of the brighter lights were studied.

5. Optimum conditions for the luminescence of lophine were determined.

* The commercial cleaning agent, "Clorox," may be used successfully for this purpose

Photo-Stability of Suspensoids[1]

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Colloidal suspensions have been shown by Young and Pingree (1) to be light-sensitive with respect to their rates of migration under electrical stress. In some cases the effect was found to be positive and in others negative.

Knowing that catalytic activity of colloidal platinum on hydrogen peroxide is destroyed by boiling, Farmer and Parker (2) in 1913 demonstrated that this activity can also be destroyed by the action of ultraviolet light.

It was pointed out by Spear (3) and his co-workers that coagulation of Bredig's platinum hydrosol was greatly accelerated by exposure to a 220 volt Cooper-Hewitt quartz lamp.

In 1929 Lal and Ganguly (4) showed that the coagulation and the accompanying change of pH of thorium hydroxide sol when exposed to the full radiation of a quartz mercury arc was due to the photochemical decomposition of the stabilizing agent, nitric acid. Similarly, the coagulation of silver in tannic acid containing a trace of potassium nitrate was explained by the photochemical decomposition of the tannic acid generating small amounts of ammonia. Their work seems to show that the coagulating effect of the rays is independent of the sign of the colloids; the oppositely charged sols coagulate at about the same rate, increasing the pH in the case of negatively charged colloids and decreasing it in the case of positively charged colloids. It was suggested that the coagulation of colloidal solutions by light is due to the chemical and photochemical decomposition of the stabilizing electrolytes.

Emulsions of benzene, benzine, and carbon disulfide in water, with sodium oleate as emulsifying agent, were separated into two layers on exposure to ultraviolet light, and this was accompanied by an increase in pH. Sinha and Ganguly (5), who studied this, indicated that the layer-breaking was partially due to the destruction of the emulsifying agent by ultraviolet radiation.

Following up the earlier work on the effect of sunlight on numerous sols, Dhar and Roy (6) and Shella (7) concluded that sols can be grouped into two classes: (a) those like iron, chromium, tellurium, aluminum, tin, and thorium hydroxides, prepared in a hot condition, and vanadium pentoxide, manganese dioxide, and mercuric sulfide, all of which are rendered unstable toward electrolytes after exposure; and (b) those like Prussian blue, copper ferrocyanide, gum dammar, and mastic, which become stabilized in the presence of electrolytes. Certain sols were coagulated by sunlight and were found to have a higher conductivity than those in the dark. The coagulation by light is thought to be due to the decomposition of the stabilizing ions and the loss of reactivity of the particles of the sols. On the analysis of the absorption

[1] This paper is constructed from a dissertation presented by David Hing Jung to the Faculty of the Graduate School of Indiana University in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Chemistry.

spectra of exposed and unexposed sols there was found to be a marked absorption in the case of arsenic trisulfide, Prussian blue, and ferric hydroxide, while gum dammar and mastic showed less disintegration on exposure to light.

In this investigation the influence of radiation of various wave-lengths on the stability of both hydrosols and organosols with respect to the effect on particle size, pH, and change on photochemical reactions are studied.

Experimental

Materials.—All the chemical reagents used in the preparation of colloidal suspensions were of C. P. quality.

The methyl, ethyl, and n-propyl alcohols were all refluxed over quick-lime for several hours and then distilled. The middle portion of the distillate was again refluxed over a small amount of lime for 10 hours before again redistilling.

The benzene used was made anhydrous and thiophene-free by shaking with concentrated sulfuric acid. This process was repeated three times, after which the benzene was distilled in the presence of calcium chloride. The middle fraction was collected for use.

The acetone used was purified according to the method of Shipsey and Werner **(8)**.

Apparatus.—The source of ultraviolet light used in this investigation was a Cooper-Hewitt lamp of the quartz mercury vapor type manufactured by the General Electric Vapor Lamp Company of Hoboken, New Jersey. It operated on a 110 volt D. C. line, using 2.5 amperes with a fall of potential across the arc of 15 volts. The lamp, equipped with an enamelled reflector, was placed in the upper part of an asbestos lined box of the dimensions 12″ x 12″ x 16″. Inside this box or reaction chamber were placed water coils to maintain the temperature at about 28° C. In some cases a filter, No. 980 Red Purple Corex "A", of 3.5 mm. thickness, made by the Corning Glass Company, was used to filter out other wave-lengths, thus transmitting only wave-lengths from 2500 Å to 4000 Å.

The intensity of ultraviolet radiation from the lamp was measured according to the method described by Anderson and Robinson **(9)**. In five hours, 37.8 mg. of oxalic acid were decomposed, or 3.91×10^5 ergs per second were required to decompose 1 mg. of oxalic acid in 30 minutes.

The infrared and visible radiations were obtained from a Thermo-Ray lamp built by the McIntosh Electrical Corporation of Chicago. It was equipped with a 1000-watt tungsten filament and nitrogen-filled bulb, Luchiesh, M. **(10)**. This lamp was placed in the upper compartment of a large wooden box. In the shelf which divided the upper compartment from the lower, was fitted a light filter, Sextant Red, 6″ x 6″ and 3.5 mm. thick, manufactured by the Corning Glass Company. Thus the box served a dual purpose. The upper compartment was used for visible light which, when passed through the filter into the lower compartment, gave infrared rays of the wave-lengths 8000 Å to 10,000 Å.

Preparation of Colloidal Suspensions.—Bismuth hydroxide hydrosol was prepared by adding with constant stirring 150 ml. of concentrated ammonium hydroxide to 300 ml. N/10 bismuth nitrate. The bismuth hydroxide, when washed free of basic salt by centrifuging and subsequent decantation, becomes dispersed in pure water. The concentration of the sol was 1.8 grams per liter.

Aluminum hydroxide hydrosol was prepared by precipitating 5.78 g. of aluminum chloride hexahydrate in 200 ml. of water with ammonium hydroxide. The precipitate was washed with hot water and transferred to a flask containing 500 ml. of water, to which was added just enough N/20 hydrochloric acid to bring about peptization. The suspension was then heated to boiling.

Arsenious sulfide hydrosol was prepared by diluting 200 ml. of a cold saturated solution of arsenious oxide to 400 ml. and adding it slowly to a solution made by saturating 2 ml. of water with hydrogen sulfide which was then diluted to 200 ml. The mixture was then diluted to two liters with a hydrogen sulfide solution ten times as strong. The whole was then treated with hydrogen sulfide gas until completely saturated. The resulting yellow sol was then divided into two portions, one of which was subjected to boiling to remove the excess hydrogen sulfide and marked *Sol 1*. The other portion was treated with hydrogen gas to remove the excess hydrogen sulfide and marked *Sol 2*. The concentration of these sols was found to be 18.7 g. arsenic trifulfide per liter.

Cadmium sulfide hydrosol was prepared by precipitating cadmium sulfide by adding ammonium sulfide solution to cadmium nitrate solution. The precipitate was washed free of excess ammonium sulfide. Suspension was brought about by bubbling hydrogen sulfide, which has a peptizing action, through the solution **(11)**. The excess hydrogen sulfide was removed by passing hydrogen gas through the suspension. The concentration of the resulting hydrosol was found to be 2.7 g. per liter.

Antimony sulfide hydrosol was made by passing hydrogen sulfide gas through a solution of 5 g. potassium antimony tartrate in one liter of water. The resulting suspension was dialyzed for three days at room temperature.

Zinc sulfide hydrosol was formed by passing hydrogen sulfide gas into water containing in suspension pure zinc hydroxide, which was previously precipitated by ammonium hydroxide from the chloride salt according to the method of Taylor **(12)**.

Sulfur hydrosol was prepared in the usual manner by passing hydrogen sulfide gas into water saturated with sulfur dioxide.

Mercuric sulfide n-propyl alcosol was prepared by pouring slowly a solution of 0.75 g. of mercuric cyanide into 250 ml. of n-propyl alcohol saturated with hydrogen sulfide. A deep brown sol formed immediately and turned black rapidly. Dry hydrogen gas was then passed through the sol for 24 hours, removing the excess hydrogen sulfide (Weiser and Mack, 13). The concentration was found to be 1.0 g. per liter.

Mercuric sulfide ethyl alcosol was prepared by disolving mercuric cyanide in absolute alcohol and treating with dry hydrogen sulfide gas,

(Errera, **14**). The resulting alcosol contained 2.5 g. mercuric sulfide per liter.

Mercuric sulfide sol in acetone was prepared in the same manner as mercuric sulfide ethyl alcosol.

Copper sulfide ethyl alcosol was prepared in a manner similar to that used in preparing the mercuric sulfide, using copper acetate. The resulting suspension was found to contain 37 g. cupric sulfide per liter.

Arsenious sulfide sol in nitrobenzene was prepared in the way described by Galt (**15**).

Sulfur sol in benzene was prepared in a manner similar to that used by Bikerman (**16**). The resulting sol contained 0.6% sulfur.

Suspensions of magnesium, barium, and calcium carbonates in ethyl alcohol were prepared according to the method outlined by A. van Busbagh (**17, 18**). The concentration of these sols was found to be about ten grams per liter.

A 2% suspension of sodium caseinate was prepared and used as the casein hydrosol.

Purified Chinese egg albumin was used in preparing the albumin suspension. Ten grams were suspended in 500 ml. of water.

Ash-free gelatin was prepared according to the improved method described by Loeb (**19**).

Soybean protein, containing mostly glycinin, was prepared in exactly the same manner as the casein hydrosol mentioned above.

Procedure.—Fifteen-ml. portions of the sols were exposed to the different radiations for a definite period of time in quartz flasks (ultra-violet), small crystallizing dishes (infra-red), and specially-blown thin-walled glass flasks (visible). The sols were kept at a distance of 15 mm. from the source of light in all cases. A similar portion of the same sol was kept in a dark chamber at about the same temperature for comparison.

The pH of the clear or nearly clear supernatant liquid of the sols which had been coagulated by light was determined and this value compared with the pH of clear sols obtained by centrifuging the sols (2200 R. P. M.) of shorter radiation periods or no radiation (in dark). The hydrogen electrode was used for the alkaline suspension and the quinhydrone electrode for the acid protein solutions. The Helige colorimetric comparator was used for some of the emulsoids. The effect of radiations on pH of the suspensions is given in Table I.

In order to determine the coagulating power of different electrolytes, a measured volume of the sol was placed into a clean graduated test tube and made up to 5 ml. while a known amount of a standard solution of an electrolyte was placed into another tube and was also made up to 5 ml. The two solutions were then carefully mixed, and one hour later coagulation was noted. The liminal values of electrolyte concentration were determined according to Thomas (**22**). The results are expressed as ml. of electrolyte which must be diluted to 5 ml. in order to bring about coagulation in one hour and are recorded in Table II.

Discussion of Results

Aluminum hydroxide sol was completely coagulated in 24 hours under visible and infrared radiation and in 22 hours under ultraviolet.

Both arsenious sulfide hydrosols were completely coagulated in six hours, with the exception of those exposed to infrared rays, which took 52 hours before any settling was noticed. The sols first became turbid but retained their original color. Later the sols appeared partly precipitated, but the supernatant liquid was still pale yellowish white. Finally the sols precipitated completely, leaving a clear liquid and a mass of free sulfur particles settling on the bottom of the dish. Under infrared rays there was no apparent change except on prolonged exposure, when a small amount of free sulfur settled on the dish. The antimony, cadmium, and zinc sulfides showed about the same changes as arsenic trisulfide at first except that the red-orange color of the antimony trisulfide became orange and the cadmium sulfide coagulated more rapidly, leaving the supernatant liquid clear. The increase in particle size of these sols on exposure was easily observed by means of the Tyndall

TABLE I.—Effect of Radiations on pH of Suspensions

SOL	Time of Exposure (hours)	pH				
		Ultraviolet		Visible	Infrared	Absence of light
Bismuth Hydroxide	2	6.60		6.51	6.50	6.42
	4	6.69		6.60	6.56	
	8	6.80		6.70	6.62	
	10	6.81		6.72	6.66	
Aluminum Hydroxide	2	6.54		6.46	6.42	6.35
	4	6.63		6.53	6.47	
	8	6.67		6.58	6.50	
	12	6.66		6.60	6.51	
Arsenious Sulfide Sol 1	0.5	3.78	3.93*	4.07	——	4.38
	1	3.54	3.73	3.91	4.55	
	2	3.35	3.58	3.85	4.72	
	4	3.20	3.42	——	——	
	5	——	——	3.83	4.90	
	6	3.11	3.42	——	——	
	8	2.90	——	——	5.13	
	9	——	3.40	——	——	
	10	2.88	——	3.76	5.22	
Arsenious Sulfide Sol 2	1	3.67	4.05	——	——	4.45
	2	3.32	3.64	3.95	——	
	3	——	——	——	5.05	
	4	3.10	3.40	——	——	
	5	——	——	3.82	——	
	6	2.95	3.31	——	5.26	
	8	2.89	3.30	——	——	
	10	2.80	3.30	3.77	5.36	
Cadmium Sulfide	1	3.18		3.25	3.20	3.55
	2	3.05		3.15	——	
	4	3.00		3.14	3.12	
	7	2.88		3.10	3.06	
Antimony Sulfide	1	3.80		——	——	4.05
	2	3.64		3.90	4.10	
	4	3.43		——	——	
	5	——		3.83	4.14	
	6	3.24		——	——	
	8	3.15		——	——	
	10	3.08		3.77	4.17	

*Ultraviolet light used with filter in the experiments reported in this column.

TABLE I.—Effect of Radiation on pH of Suspension—Continued

SOL	Time of Exposure (hours)	pH			
		Ultraviolet	Visible	Infrared	Absence of light
Zinc Sulfide	1	3.60	3.58	3.55	3.85
	2	3.45	3.45	3.43	
	4	3.32	3.40	3.39	
	8	3.30	3.39	3.38	
	10	3.30	3.38	3.32	
ORGANOSOLS					
Mercuric Sulfide n- propyl alcosol	5	4.87	4.91	5.00	5.28
	10	4.78	4.82	4.87	
	15	4.74	4.78	4.81	
Mercuric Sulfide ethyl alcosol	5	4.83	4.89	4.92	5.30
	10	4.72	4.76	4.79	
	15	4.68	4.70	4.75	
Mercuric Sulfide in acetone	10	2.86	2.47	2.53	3.25
Copper Sulfide ethyl alcosol	5	3.38	3.47	3.58	3.92
	10	3.25	3.35	3.39	
	15	3.21	3.24	3.30	
Magnesium Carbonate ethyl alcosol	10	7.51	7.98	7.76	7.05
	20	7.82	8.19	8.10	
	30	8.06	8.20	8.10	
Barium Carbonate ethyl alcosol	10	7.55	8.02	7.70	6.98
	20	7.93	8.20	8.05	
	30	8.10	8.20	8.15	
Calcium Carbonate ethyl alcosol	10	7.37	7.80	7.65	7.08
	20	7.43	8.05	7.94	
	30	8.00	8.10	8.04	
Sodium Caseinate	4	7.35	7.42	7.44	7.64
	8	7.24	7.30	7.37	
	12	7.20	7.25	7.28	
Egg Albumin	2	7.60	7.62	7.63	7.83
	4	7.52	7.55	7.59	
	8	7.43	7.46	7.50	
	12	7.38	7.40	7.46	
Gelatin	5	7.73	7.63	7.85	7.90
	10	7.56	7.54	7.63	
	20	7.49	7.50	7.58	
	30	7.44	7.47	7.55	
Glycinin	5	7.45	7.30	7.35	7.56
	8	7.28	7.25	7.22	
	10	7.25	7.18	7.20	

effect. The yellowish beam became reddish with the increase in particle size due to prolonged exposure.

Sulfur sol is so sensitive to light that it coagulated completely in half an hour exposure to all wave-lengths.

The zinc sulfide hydrosol coagulated in 35 hours under visible rays, 29 hours under ultraviolet, and 38 hours under infrared radiation.

The mercuric sulfide ethyl alcosol coagulated in 55 hours under visible, 58 hours under infrared, and 38 hours under ultraviolet.

Sulfur suspended in benzene did not coagulate in 15 hours.

The results in the preceding tables show that the basic protein sols of casein, egg albumin, gelatin, and glycinin under the influence of light

TABLE II.—Coagulation by Electrolytes

SOL	Electrolyte	Expos. (Hours)	Ml. electrolyte required to produce coagulation in 1 hour			
			Ultra-violet	Visible	Infrared	No exposure
HYDROSOLS						
Bismuth, hydroxide	N KCl	4	2.55	2.60	3.62	2.84
	N/10 Na_2SO_4	8	3.07	3.12	3.15	3.25
Zinc, sulfide	N KCl	8	2.15	2.20	2.25	2.58
	N/10 Na_2SO_4	8	3.32	3.40	3.37	3.65
	N/13 $FeCl_3$	8	1.85	1.90	2.00	2.20
ORGANOSOLS						
Mercuric, sulfide, n-propyl, alcosol	N/10 KCl	5	2.05	2.18	2.08	2.15
	N/10 LiCl	5	1.57	1.52	1.60	1.50
	N/10 KCl	10	2.00	2.15	2.20	——
	N/10 LiCl	10	1.45	1.50	1.55	——
Mercuric, sulfide, ethyl, alcosol	N/10 KCl	5	3.45	3.56	3.55	3.64
	N/10 LiCl	5	1.46	1.52	1.50	1.65
	N/10 KCl	15	3.40	3.45	3.50	——
	N/10 LiCl	15	1.40	1.47	1.43	——
Mercuric, sulfide in acetone	N/50 LiCl	10	2.32	3.15	2.30	2.45
Copper, sulfide, ethyl, alcosol	N/10 KCl	5	3.95	4.00	4.50	4.84
	N/10 LiCl	5	1.80	1.85	1.88	2.05
	N/10 KCl	15	3.90	3.95	4.20	——
	N/10 LiCl	15	1.67	1.79	1.70	——
Magnesium, carbonate, ethyl, alcosol	N/10 LiCl	10	0.42	0.35	0.42	0.75
	N/10 LiCl	15	0.40	0.30	0.32	——
	N/100 $NaC_2H_3O_2$	10	1.37	1.15	1.22	1.75
	N/100 $NaC_2H_3O_2$	15	1.29	1.10	1.20	——
Barium, carbonate, ethyl, alcosol	N/10 LiCl	10	0.35	0.33	0.38	0.68
	N/10 LiCl	15	0.23	0.30	0.32	——
	N/100 $NaC_2H_3O_2$	10	1.40	1.25	1.33	1.60
	N/100 $NaC_2H_3O_2$	15	1.35	1.30	1.32	——
Calcium, carbonate, ethyl, alcosol	N/10 LiCl	10	0.35	0.24	0.30	0.80
	N/100 $NaC_2H_3O_2$	10	1.42	1.25	1.30	1.72
PROTEIN SOLS						
Casein sol	N/13 $FeCl_3$	8	2.17	2.22	2.28	2.34
Albumin sol	N/13 $FeCl_3$	8	2.38	2.44	2.40	2.65
Gelatin sol	N/13 $FeCl_3$	8	2.95	2.84	2.87	3.15
Glycinin sol	N/13 $FeCl_3$	8	2.20	2.32	2.25	2.85

rays become unstable toward electrolytes when near a pH of 7 after prolonged exposure.

Conclusions

In general the experimental results give credence to the theory that radiations over a wide range of wave-lengths have a decided influence on the stability of colloids, both hydrosols and organosols. This effect, according to Charem **(20)** and Slintizing **(21)**, is not solely a physical process but a photo-activated chemical change in either the dispersion medium or the stabilizing ions present.

The pH changes are credited to the chemical reactions induced by radiation on these sols. The increase in pH in the case of hydroxide hydrosols was due to the photo-chemical decomposition of small quantities of acid, especially nitric, which remains in the colloidal system as a stabilizing agent. The decomposition of the acid thus rendered the colloids less stable than before exposure.

In an analogous manner the decomposition of carbonic acid to carbon dioxide by various radiations of light accounts for the increase in pH of the alkaline carbonate alcosols. Consequently, the unexpected results of the pH of the arsenic trisulfide hydrosols after exposure to infrared rays may be due to the decomposition, rather than the oxidation, of the hydrogen sulfide which is present in small amounts.

On the other hand, the pH values of sulfide hydrosols and organosols, particularly the arsenic trisulfide and antimony trisulfide under visible and ultraviolet radiations, were decreased. This is probably due to the oxidation of a trace of hydrogen sulfide (which is present in the colloidal system as a stabilizing ion adsorbed on the surface of the colloidal micelles) to thionic acids by the radiations. On further exposure a secondary reaction may occur between the hydrogen sulfide and its oxidation products which would produce sulfur in small amounts. This colloidal sulfur might remain suspended for a time, but as exposure was continued, more sulfur would precipitate and the suspension finally settle when the concentration of sulfur became sufficiently large.

The organosols were more difficultly coagulated by various radiations due to the fact that there is an insufficient amount of water present to bring about the oxidation of the hydrogen sulfide present in the system.

Since the influence on the stability of lyophobic colloids and organosols can be accounted for, at least quantitatively, by considering the effect upon the dielectric constant of the medium, on the ionization of the electrolytes present, and on the selective adsorption of ions by the colloidal micelles, it is not to be expected that the organosols would behave in the same way toward light as the corresponding hydrosol would. In fact, the hydrosols themselves are governed to some extent by the above factors. However, the sols of both these classes become unstable toward electrolytes and can be coagulated by subjecting to radiations of various wave-lengths. It is evident that the light-rays can act by photochemical means to disturb or destroy the stabilizing ions adsorbed on the surface of the colloid micelles, thus bringing about instability and subsequent coagulation of the colloids.

It may be seen from Table II that all colloids studied became less stable toward electrolytes on prolonged exposure to all wave-lengths used in this investigation. This is to be expected if light rays actually disturb the adsorbed stabilizing ions.

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A Detailed Study of a Reaction Used for the Preparation of Alkyl Mandelic Acids

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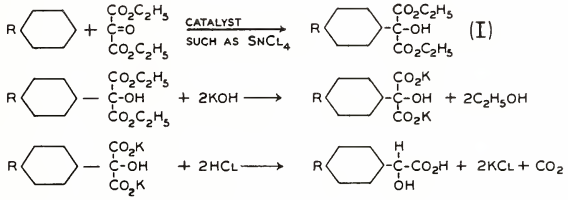
We have been interested in the preparation of substituted mandelic acids. Up to the present most of our work has been confined to the alkyl substituted type.

The most common methods for the preparation of mandelic acids has been to treat an aldehyde such as benzaldehyde with hydrogen cyanide, and then to hydrolyze the nitrile thus formed to the acid. This method would be reasonably satisfactory if all the desired aldehydes were readily available. Since the synthesis of these aldehydes requires much time and is often accompanied by poor yields, another method suggested by Ando[1] has been used. The essential features of the method may be represented by the following equations:



Since the process proved to be rather general in its application, it was considered worth while to make a careful study of the conditions of time, temperature, and concentrations of reagents to produce the best yields. In addition, we have tried the effects of various catalysts and have tried a variety of solvents as reaction media.

For the purpose of this study, toluene was chosen as a representative hydrocarbon, thus producing p-methyl mandelic acid as the final product.

Experimental

Reagents.—The toluene was purified by distilling the stock reagent from sodium through a suitable column. Ethyl oxomalonate was prepared using the directions in Organic Syntheses.[2]

The general procedure for the reaction was as follows. The toluene and ethyl oxomalonate were mixed in a 3-necked round-bottomed flask fitted with a stirrer, a condenser, and a burette carrying the stannic chloride. Suitable precautions were taken to exclude moisture. The stannic chloride was added dropwise with stirring, and stirring continued for the desired length of time. In most cases during the addi-

[1] Ando, 1935. Jour. Chem. Soc. Japan 56:745-756; Chem. Abstr. 29:7960.
[2] Gilman, 1932. Organic Syntheses (Collective Vol. I). John Wiley and Sons, New York. p. 261.

tion of stannic chloride, a solid separated, and the supernatant liquid became pink to deep red in color. The mixture was poured into water acidified with hydrochloric acid. This liquid mixture was extracted with ether, and the ethereal solution washed with water until the washings were chloride free and then dried with calcium chloride and distilled. The excess of toluene was recovered and the intermediate compound (I) collected at 150-155° at 5 mm. The intermediate was weighed to determine the yields since it was found that this product could be saponified to give almost a quantitative yield of p-methyl mandelic acid. All yields throughout this discussion were calculated on the basis of the ethyl oxomalonate used.

The first series of experiments was designed to learn the optimum concentration of the hydrocarbon to use. Five one-hundredths of a mole (8.7 g.) of ethyl oxomalonate, 0.05 mole (13.0 g.) stannic chloride, and varying amounts of toluene were reacted. About thirty minutes were required to add stannic chloride, and stirring was continued for fifteen minutes longer. The temperature was held at 20° during the reaction and the mixture allowed to stand at the same temperature for forty-eight hours. The product was then treated by the general procedure and the intermediate compound collected and weighed.

TABLE I.—Yields of intermediate using varying amounts of toluene

Moles toluene used	Yield %
0.05	44.9
0.10	47.7
0.20	52.8
0.30	53.8
0.40	55.3
0.60	57.7

In the second series of reactions, 0.25 moles of toluene, 0.05 moles ethyl oxomalonate and varying amounts of stannic chloride were reacted at 20°. The stannic chloride was added dropwise, and stirring was continued for fifteen minutes after the last was added. The mixtures then stood at 20° for 48 hours. Table II shows the data.

TABLE II.—Yield of intermediate using varying amounts of Stannic Chloride

Moles Stannic Chloride used	Yield %
.031	46.2
.042	51.5
.057	57.9
.077	59.7
.100	58.6

In the third series of reactions 0.05 moles of ethyl oxomalonate, 0.077 moles stannic chloride and 0.25 moles toluene were reacted at 20°. The addition of stannic chloride and stirring was carried out over a period of two hours, and the reaction mixture allowed to stand for varying periods of time. Table III summarizes the data.

TABLE III.—Yield of intermediate varying the reaction time

Time	Yield %
2 hours	55.6
6 hours	59.9
1 day	59.1
2 days	58.4
4 days	59.3
6 days	59.1

In the fourth series, the same concentrations of reagents were used as in the third, the reaction was continued two hours with stirring, and the temperature was varied. The reaction product was immediately poured into ice water at the end of two hours. Table IV shows the results.

TABLE IV.—Yield of intermediate varying the temperature of the reaction

Temperature (°C)	Yield %
−10	55.3
5	56.0
20	55.6
70	29.7

To determine the effect of adding the reagents in a different order, 0.25 mole of toluene, and 0.077 mole of stannic chloride were mixed, and ethyl oxomalonate was added drop by drop, and stirring was continued for two hours at −10° C. The yield of the intermediate was 41.4%.

The effect of various catalysts.—These reactions were carried out using 0.25 mole of toluene, 0.05 mole of ethyl oxomalonate and 0.10 mole of each of the catalysts. The procedure was the same as for the stannic chloride except the solid anhydrous catalysts and toluene were mixed and the ethyl oxomalonate was added. The temperature was 0°C., and the reaction time three hours. The data are summarized in Table V.

TABLE V.—Yield of intermediate using various catalysts

Catalyst	Yield %
Stannic Chloride	60.2
Ferric Chloride	56.3
Aluminum Chloride	negligible
Zinc Chloride	negligible
Cuprous Chloride	negligible

Finally, 0.25 mole toluene, 0.05 mole of ethyl oxomalonate, and 0.077 mole of stannic chloride were reacted at 0°C. and for three hours in 25 grams of various solvents. Table VI shows the results.

TABLE VI.—Yield of intermediate using various solvents for reaction media

Solvent	Yield %
Petroleum ether (b.p. 30-40°)	41.2
Chloroform	53.3
Carbon Tetrachloride	60.7
Carbon Disulphide	60.4
Methyl Alcohol	20.6
Acetone	negligible
Ether	negligible

Discussion of Results.—From the tables it can be seen that the best yields are obtained by using five moles of toluene to one mole of ethyl oxomalonate. Fortunately, the excess of hydrocarbon can be recovered with almost no loss. The optimum quantity of stannic chloride is about one to one and five-tenths moles of the chloride to one mole of the ester. Increased amounts of the chloride make little difference.

The yield changes slightly whether the reaction mixture stands for three hours or for six days, and little difference is noted in the yields from minus ten degrees up to room temperature. At higher temperatures a different product forms, which is much higher boiling than the product desired. We hope to obtain more of this material and examine it in the future.

This reaction seems to be a special case of the Friedel-Craft type. Four reasons for this suggestion may be cited.

1. In appearance it is quite similar to the reaction of benzene with acetyl chloride to give acetophenone. In this reaction we might consider the first step to be an addition of phenyl and hydrogen to a carbonyl oxygen followed by the loss of a molecule of hydrogen chloride. In the case under consideration, however, the intermediate may be considered as an addition of the hydrocarbon to a carbonyl ozygen, but there is no group present which splits out easily.

2. The condensing agents, stannic chloride, and ferric chloride favor the Friedel-Craft reaction just as this one. The fact that aluminum chloride, which is highly desirable in most Friedel-Craft reactions, did not produce the results desired here, is not necessarily an argument against the above suggestion. Aluminum chloride did cause a reaction, but the product formed had a very high boiling point. This probably means that two or three moles of the ester reacted with one mole of the hydrocarbon to produce a complex derivative or a complex mixture. It is possible that if the temperature had been much lower and if a solvent had been present, the desired product would have been produced. This experiment has not been tried.

3. The fact that carbon disulfide, when used as a solvent, gave a good yield, as it does in most Friedel-Craft reactions, points in the same direction.

4. Finally, when nitrobenzene and ethyl oxomalonate are mixed in the presence of stannic chloride, no reaction takes place. This has its parallel in the Friedel-Craft reaction, in which nitrobenzene is often used as a solvent.

Summary

1. A method for the preparation of alkyl mandelic acids has been studied in detail using the preparation of p-methyl mandelic acid as an example.

2. The optimum reaction conditions have been discovered.

3. The reaction is believed to be of the Friedel-Craft type.

PROGRAM OF THE SECTION ON GEOLOGY AND GEOGRAPHY

Chairman: W. LeRoy Perkins, Indiana State Teachers College

1. The droughts of 1930, 1934, and 1936, and their relation to crop production in Indiana and other states of the Corn Belt. J. E. Switzer, Indiana University.
2. The Geomorph; an earth museum-laboratory. Alfred H. Meyer, Valparaiso University.
3. The mineral wool industry of Indiana. William D. Thornbury, Indiana University.
4. The changing northern and western boundaries of Indiana territory and state. Robert W. Karpinski, Indiana State Teachers College.
5. On the true nature of a polished surface of a gem stone. Frank B. Wade, Shortridge High School, Indianapolis.
6. Regional contrasts in Indiana deaths from violence. (Death rate study No. 4). Stephen S. Visher, Indiana University.
7. The surface geology of Bartholomew and Brown counties. H. P. Ulrich, Purdue Agricultural Experiment Station.
8. The Columbia Basin reclamation project. Wallace T. Buckley, Indiana University.
9. High lights of the Purdue Institute of American Policy and Technology. Frank R. Hall, Purdue University.
10. The nature of some favorable oil-bearing structures in the Pennsylvanian of southwestern Indiana. Clyde A. Malott, Indiana University.
11. Some observed effects of certain atmospheric variations. A. V. Lott, Sellersburg.
12. An exposure of New Corydon limestone in a new quarry at Huntington, Indiana. Fred J. Breeze, Fort Wayne.

The paper by S. S. Visher on regional contrasts in rainfall in Indiana, an abstract of which is given below, was presented in the General Session.

S. S. Visher, Indiana University, was elected chairman of the Section for 1938.

ABSTRACTS

The Geomorph; an earth museum laboratory. Alfred H. Meyer, Valparaiso University.—Growing interest is manifested in various model constructions showing in miniature some geologic structure, type of landscape, or actual geographic region. Always recognized as one of the most effective aids in teaching the facts of earth science, model earth exhibits have a special appeal at present in connection with the federal and state projects in regional planning. The Geomorph is intro-

duced as a type of geologic-geographic model which not only figures land surface and structural features of the earth's crust but actually reproduces the structural materials of which the earth is composed. Genuine rocks, minerals, and fossils constitute the exclusive covering of the basic skeleton made of corrugated cardboard, papier mache, and plaster. Being composed of actual earth materials arranged in proper natural earth relationships, the Geomorph functions not merely as a public museum exhibit but as a laboratory device regularly used to illustrate the forms and principles of physiographical, structural, historical, and economical geology and geography.

The changing northern and western boundaries of Indiana territory and state. ROBERT W. KARPINSKI, Indiana State Teachers College.— The map by Delamarche of 1785 shows *Indiana* marked in the northwestern part of Virginia on the southeast side of the Ohio River. This marking of the *Indiana Company* was carried on many of the early maps from about 1785 until, in the case of some of the European maps of North America, as recently as 1815. At times a marking of *Indiana* in northwestern Virginia would be found on the same map indicating Indiana in its proper place in the Northwest Territory. This was undoubtedly the first use of the name to represent any considerable area in the United States. Following the proposed Jeffersonian division of the Northwest Territory into ten states, none of which were to carry the name *Indiana*, the next proposal blocked the Northwest Territory off into five regions, the northern limit of the southern tier of states being shown on the Abraham Bradley, Jr., map of 1796, by a line running east and west through the southernmost point of Lake Michigan. The proposed middle state corresponds roughly to the limits which later were to be made for Indiana.

On the Carey map of 1801, *Indiana* territory was marked off. The western limit of the section to be known as the Territory Northwest of the Ohio was not marked; only the Grenville Treaty line was shown running from the Ohio River north to Fort Recovery and then east. Four years later, however, on the Carey map of 1805, Indiana territory was limited on the north by the east-west line running from the tip of Lake Michigan and on the west by the Mississippi River. The so-called gore is visible here. On the map by Carey in 1814, at the southern tip of a curiously deformed Lake Michigan we have the northern boundary of Indiana, Illinois, and Ohio, running east-west, and a very narrow Indiana. Another remarkable feature on this map is the unusual configuration of the Wabash in its lower sections. The correct marking of the Wabash in the section north of Vincennes was to be of some importance in establishing the boundary between Illinois and Indiana. Another map by Carey of 1814 has a much more accurate representation of Lake Michigan and a more normal western boundary for Indiana although it is still a straight western boundary line, instead of following the Wabash in the southwestern section. A new northern boundary for Indiana, in which Lake Michigan occupies about the central section, is noted.

The Arrowsmith map of the United States (1825) has a representation which is characteristic of some of the important Indiana maps for

a period of ten or fifteen years and of Michigan's southern peninsular section for about 40 years. Like the large Mitchell map, it was copied quite frequently by other map makers.

On the Melish map of 1816 we have still another configuration on the northwestern boundaries of Indiana characterized by the indentation where Lake Michigan juts into the central part of northern Indiana and by the southwestern section following the Wabash River. Melish was one of the foremost cartographers during the first quarter of the nineteenth century and the man responsible for one of the earliest maps of Indiana alone.

On the detailed map of Indiana in 1822 by Lucas, we see the southern tiers of counties very well represented with a large Delaware and Wabash county to the north. The City of Indianapolis, for which land was first sold in 1821, is shown. On the Melish map of the United States (1822) we have another one of the characteristic configurations of Indiana and a curious western boundary for Michigan.

On the true nature of a polished surface of a gem stone. FRANK B. WADE, Shortridge High School, Indianapolis.—Evidences obtained from practical experience in the polishing of gem material tend to support the theory that there is more or less "flow" of the surface material and the formation of the so called "Beilby layer."

Regional contrasts in Indiana deaths from violence (Death rate study No. 4). STEPHEN S. VISHER, Indiana University.—Earlier studies of Indiana death rates have revealed conspicuous regional contrasts in the deaths caused by several diseases and also in total deaths. (Proc. Indiana Acad. Sci. for 1923, 1924, 1935.) This study of deaths due to violence, suicide, and homicide is based on the official data for five years, a total of about 1,000 homicides and 3,100 suicides.

The northern, central, and southern regions show a regular southward increase in homicides in proportion to population if the chief urban county of each is excluded. Southern Indiana has a half more homicides per 10,000 people than does northern Indiana.

The six counties which had relatively most negroes at the last census had an average homicide rate just twice that for the state as a whole. On the other hand, although Lake county has relatively many negroes as well as foreign born, the homicide rate in the six counties with relatively many foreign born was only slightly above the state average. The chief coal-mining counties had a moderately high rate; the most strictly rural counties had a relatively low rate, except in south central Indiana. The most urban counties, except Allen (Fort Wayne), had higher than average rates. The homicide rate is relatively high in the state's peripheral counties and in Marion (Indianapolis).

The distribution of suicides contrasts sharply with that of homicides; suicides are relatively most frequent in the interior counties of the state; none of the peripheral counties have relatively many suicides. The suicide rate is relatively high in nearly all counties which had fewer people in 1930 than in 1900 or 1890. Such counties have relatively many elderly people, and apparently also relatively many dis-

couraged people. Suicides are relatively common in proportion to population in the most strictly rural counties, and among such counties there is a distinct southward increase in regional averages. Marion county is the only urban county with fairly numerous suicides in proportion to population, and its rate is only slightly more than the average for the state.

The surface geology of Bartholomew and Brown counties. H. P. ULRICH, Purdue Agricultural Experiment Station.—A study of the geology of Bartholomew and Brown counties in connection with the soil survey of these areas was made in 1936. Since the geological material is one of the many factors entering into soil formation, it is possible to make detailed and accurate determinations of many of the geological formations without having technical training along this line. The extent and boundaries of Early and Late Wisconsin and Illinoian till and associated stratified alluvial deposits have been determined, as well as the location of sandstone, siltstone, shale, and limestones of the various formations. Particular attention was paid to the location of the probable outer limits of the Illinoian glacial border, as has been indicated by shallow till deposits and land form.

The Columbia Basin reclamation project. WALLACE T. BUCKLEY, Indiana University.—Within the limits set by the relief, rainfall has been the chief limiting factor in the occupation of the Columbia Basin. With the building of the Northern Pacific railroad the early mining, farming, and fur-trading ventures began, about 1880, to give way to a large scale development of the Pacific Northwest, and by 1910 the population had increased to about 400,000, at which point it remained until 1930. In this period it is evident that a static level had been reached in mining, lumbering, and wheat growing. Such slight increases as were detectable could be traced to the effects of irrigation. Large areas of arid land in the central part of the Basin invited exploitation, however, and dry-farming was attempted. It soon became obvious that any extensive agriculture in the section would be based on irrigation. Since 1904 the Columbia Basin Reclamation Project has been kept alive by various business interests, but none of the many proposed projects were able to attract private, state, or federal funds. The present project, centered around the Grand Coulee dam and pumping plant, was at first justified as much for power development and flood and navigation control as for reclamation, but it is evident that it will soon make irrigation possible. It is estimated that the first settlements on the project will occur in 1940 and that eventually 1,200,000 acres will be reclaimed, making possible an increase in population of 400,000.

The nature of some favorable oil-bearing structures in the Pennsylvanian of southwestern Indiana. CLYDE A. MALOTT, Indiana University.—Altitude data on key beds in the Pennsylvanian system of southwestern Indiana reveal a rather surprising number of departures from the simple homoclinal descent of the beds into the Illinois Basin on the west. These departures are in the form of shallow dip-descending or oblique synclines, small anticlines, shallow basins, noses, terraces,

and other irregularities. These features are superposed on the regional westerly dip and locally are so prominent that the regional dip itself is obscure. Ordinarily these features may be interpreted as features of deformation. The positive structures in Posey and Vanderburgh counties indicate that they are the result of differential compaction in the formations where sand masses are present in the dominating shales of the system. Some of the structures appear to be formed by thick sand masses at shallow depths, and are too shallow to contain oil. Others are formed over sand bodies at considerable depth in the system, and oil and gas may be found in the top of the thick sand masses or in shallower horizons higher up in the structures. The St. Wendells and the Vienna oil fields northwest of Evansville are on small anticlinal structures produced over thick sand bodies in the upper part of the Mansfield formation at a depth of about 1200 feet. Short distances away from the axes of the anticlines, the oil-producing sands grade laterally into shales. Younger strata are arched over the oil-bearing sand bodies, and upward through nearly 1200 feet of strata still show anticlinal structures which have closures of 30 to 50 feet.

An exposure of New Corydon limestone in a new quarry at Huntington, Indiana. FRED J. BREEZE, Fort Wayne.—In a new quarry, between the France Stone Quarry and the Kelly Island Quarry of Huntington, Indiana, is an exposure of New Corydon limestone which is now held to be a phase of the Huntington formation. This exposure is at the north wall of the quarry and is 12 to 15 feet in thickness. Beneath the New Corydon beds are somewhat massive layers of very hard Huntington dolomite. At the east end of the quarry the New Corydon beds are missing, but the layers of dolomite show an unusually steep dip to the north. This quarry seems to be excavated in rocks that form the steep northward slope of bioherm.

Indiana regional contrasts in rainfall intensity and some apparent effects thereof. STEPHEN S. VISHER, Indiana University.—The time distribution or intensity of rainfall is of critical importance affecting its usefulness. It has been little studied, largely because its analysis requires much labor. With the assistance of N. Y. A. workers, the official rainfall data for Indiana have been studied in considerable detail. Scores of maps have been prepared concerning various aspects of rainfall intensity. Some of these are of the annual and seasonal frequency of monthly totals of 5 and 10 inches of rainfall. Another series shows the number of days for each of the months having rainfalls of 1 inch a day or 2 inches in two consecutive days. Another series gives the amounts of rainfall received in the greatest rainstorms of one day, of 3 consecutive days, and of 6 days, for the median year of record, for the wettest one-fifth of the years, for the wettest one-tenth of the years and for the least rainy one-tenth. Six maps give the record maximum rain falling in 1 day, in 2 consecutive days, in 3, 4, 5, and 6. Twenty maps give the percentages of the years that have had rainfalls of certain amounts, for example, 2, 3, or 5 inches in 1 day, of 2, 3, or 5 inches in 2 consecutive

days, of 3, 5, and 6 inches in 3 days, of 4, 5, or 6 inches in 4 days, of 5 or 7 inches in 5 days, of 6 in 6, of 8 in 6, of 10 inches in 6 days. An eighth series, of 24 maps, gives the monthly and seasonal distribution of rains of 1 inch a day, 2 inches in 2 days, and of the maximum 1-day, 2-day, 3-day, and 6-day rainstorms. Seven maps give the number of excessive short-period (less than a day) rains by seasons. The final series gives the record precipitation in storms of less than a day's length.

Most of these series are based upon from 40 to 90 weather bureau stations, and a record of from 30 to 46 years. They practically all show a very notable southward increase in rainfall intensity. Although southern Indiana receives in a year less than 50% more rainfall than does northern Indiana, southern Indiana has several to many times as many rainstorms of the various intensities studied, especially in the cooler months, when run-off is greatest. For example, falls of 3 inches in 1 day and of 6 inches in 6 consecutive days are more than 10 times as frequent in southwest as in northeast Indiana.

An analysis of soil erosion indicates that upon comparable slopes, surfaces, and soils, erosion is decidedly more rapid in southern than in northern Indiana. A considerable part of this difference presumably is due to the difference in the amount and intensity of the rainfall. The greater ruggedness in southern than in northern Indiana apparently is partly a result of the differences in erosion associated with the differences in rainfall. The decidedly lower average crop yields upon comparable slopes in southern than in northern Indiana apparently are also related to the more unfavorable rainfall distribution. In the south a much smaller percentage of the rainfall is useful to the crops. Largely as a result of the poorer crop yields associated with the drier and poorer soil, there are noteworthy regional contrasts in the percentage of the land in farms and crops. The comparative poverty and backwardness of the average family of southern Indiana is, therefore, seemingly related to the unfortunate rainfall distribution.

The Droughts of 1930, 1934, and 1936 in The Corn Belt and Associated Areas

J. E. SWITZER, Indiana University

The term "drought," as commonly used, refers to periods in which the rainfall is considerably less than the normal. It is the custom of the Weather Bureau to report certain years, or months, as "the driest of record." *Drought* conditions, as affecting vegetation growth and crop yields, involve at least three important factors: (a) the amount of rainfall within the time; (b) the temperature, which with air movement very largely determines the rate of evaporation; and (c) the amount of moisture stored in the soil during the previous periods.

In this paper an effort is made to point out some of the relationships between temperature and precipitation on the one hand and conditions of drought and crop yields on the other during the drought years of 1930, 1934, and 1936. The study is confined to the area of the Corn Belt and some of its associated territory.

In the Corn Belt area, many of the states reported the drought of 1930 the most severe during the period for which records have been kept. In many of those states, essentially the same statements were repeated in 1934 and again in 1936. There have probably been few times since white men have occupied the middle portion of the U. S. that three years out of seven have been years of such intense droughts. The chart (Fig. 1) indicates the monthly variation from normal precipitation and temperature of six important corn-producing states for the years 1930, 1934, and 1936. Fig. 2 shows the per acre yield of corn, wheat, and rye in the same states for the years 1930 to 1936, inclusive. A comparison of the data shown by these charts will indicate something of the inter-relationships between precipitation, temperature, and the crop yields during these years.

Climatic Conditions of 1930

Indiana[1].—Indiana had the lowest rainfall (29.70 in.) for the state as a whole since the beginning of records in 1887. Only two previous years had approached this small amount. Those were the years 1895 and 1901. Every month except January and September showed a deficiency for the state.

In the *Northern Division,* April and September were about equally moist. Approximately half the stations reported precipitation above normal for those months. Otherwise, deficiencies ranged generally from 2.62 in. to 9.29 in. One station reported a deficiency of 12.99 in.

In the *Central Division,* except for the month of September, only 13 stations reported precipitation normal or above at any time from

[1] Climatological Data, Indiana Section, 35:49-52, 1930. The data used in this paper are taken from the climatological reports of the different states and published by the U. S. Dept. of Agriculture, Weather Bureau under the title "Climatological Data."

March to December, inclusive. Deficiencies for the year ranged in this Division from 3.74 in. to 14.51 in.

In the *Southern Division*, except for September, only two stations reported precipitation as normal or above at any time from March to December. Deficiencies for the year ranged from 6.3 in. to 18.61 in.

With the exception of the month of June, at a number of stations in the *Middle* and *Southern Divisions*, nearly all stations reported temperatures above normal from April to September, inclusive. Thirty-four stations reported maximum temperatures of 106° to 113° F.

The average yield of corn per acre was about 10 bu. below the average for 1919-1928, while the yield of wheat was about 3 bu. above the average, and rye production was just about equal to the average. The drought had not yet become severe at the time of the rye and wheat harvest; hence those crops were little affected, but the yield of corn was reduced nearly one-third.

A new record of high temperature was established at 113° F. The year was considered as one of severe drought because of continued high temperatures and a marked deficiency in rainfall. Springs and creeks ran low, and the supply of water became distressingly low in many localities.

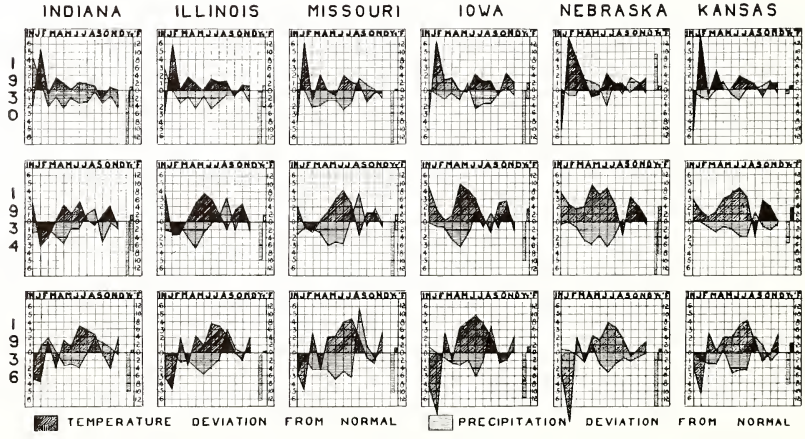


Fig. 1. This figure shows the deviation from normal precipitation and temperature by months for the states of Indiana, Illinois, Missouri, Iowa, Nebraska, and Kansas during the years of 1930, 1934, and 1936.

Illinois.—The Annual Summary for 1930 for Illinois states, "Never before, so far as climatological records show, has there been a year of such diverse temperature extremes or with a drought of such severity. January was cold, wet, and snowy, producing a new low record temperature of -35° F. while February was unusually mild."[2] Drought began in March, a month usually too wet for plowing, and permitted early plowing for oats and corn. July and August had numerous days exceeding 100° and reaching 113°, within two degrees of the highest

[2] Climatological Data, Illinois Section, 35:49, 1930.

maximum temperature ever recorded in the state. Drought did not become severe in the Northern Division until July. These conditions are shown clearly in Fig. 1. The Central Division suffered severely and the Southern more. Corn suffered relatively little in the northern part, but in some southern counties the deterioration was as much as 90%. Illinois received only 52% of its normal precipitation of the growing season. Except at two stations, the precipitation was below normal, some stations showing departures as much as 16 to 19 inches below normal for the year.

Missouri.—George Reeder, meteorologist, commenting on the weather of 1930, said,[3] "The weather of 1930 in Missouri was noteworthy from almost any standpoint. The year started with one of the coldest Januarys and deepest snow in years. A long, severe drought began in February and ran to the middle of September with only slight relief during June and the middle of August. The 40 days composed of July and the first 9 days of August were among the hottest in the weather records of Missouri. The 62-day period of July and August was the driest 62-day period of record." The spring months received only 59% of their normal precipitation. July was the outstanding driest July of record. The long drought was intensified by the extreme heat. It was in the eastern half of the state that the effects of the drought was felt most.

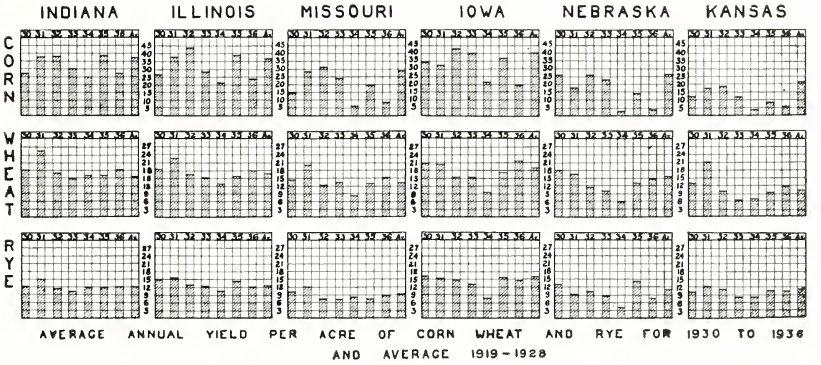


Fig. 2. This figure shows the per acre yield of corn, wheat, and rye for the states of Indiana, Illinois, Missouri, Iowa, Nebraska, and Kansas for the years 1930 to 1936, inclusive. The last bar at right for comparison shows the average per acre yield of these crops in the same states for the ten-year period, 1919-1928.

Iowa.[4]—Weather conditions in Iowa in 1930 were characterized by extremes. Only one year in the previous 58 had been warmer. The temperature ranged from –37° F. to 113° F., a range of 150 degrees. January temperature was much below normal, while February was the mildest February on record. Yet a cold wave brought a temperature of –34° F. at Webster City on the 15th. A rapid rise in temperature at

[3] U. S. Dept. of Agri., Weather Bureau, Climatological Data, Missouri Section, 34:49, 1930.

[4] Climatological Data, Iowa Section, 41:99-106, 1930.

the same place brought a maximum of 72° F. on the 24th, an absolute range of 106° in 9 days. The extreme range for the state in February was 114°, the highest range for February on record. A heavy snowfall in January was dissipated by the warmth of February, and the precipitation of February was below normal. March was only slightly warmer than February and was unusually dry, with little snow cover.

A warm April gave early start to the pastures and caused corn to be planted unusually early. Temperature and rainfall of May were nearly normal. Unusual heavy downpours in June brought the state average to 1.33 in. above normal for the month. From the first week of July, precipitation for 12 successive weeks was in general below normal. Sporadic distribution of rain and high temperatures caused severe drought conditions to be felt first in the western part, and spread eastward. The worst portion of the drought extended through a period of 82 days from July 5 to September 24.

All stations in the state reported temperatures above normal throughout July, August, and September except in the Northern Division in September. Temperatures of 100° F. or more were recorded throughout the state on 8.8 days' average in July and August. August 3, with a temperature of 106.36°, was probably the hottest single day in Iowa in a century.

The drought was broken by generous rains on September 25 and 26.

Nebraska.[5]—In contrast with the states farther east, Nebraska in 1930 gave practically no indication of drought. The year as a whole was relatively warm and wet. The months with excess and deficiency in temperature or moisture practically balanced each other as shown in Fig. 1. The rainfall of April-August was 95% of normal in the eastern one-third and 22% above normal in the western two-thirds of the state. The only indications of drought conditions were in a relatively dry winter, extending from December, 1929, through March, 1930, and hot dry weather during the last half of July. The latter did considerable damage to corn and pasture crops. This was partly balanced by ample rains during the last half of August.

Kansas.[6]—"In Kansas, 1930 was a year of extremes, yet the precipitation for the state, as a whole, was exactly normal and the average temperature was only one degree above normal." April and May were so wet that planting corn was delayed. A hot and dry spell began the latter part of June and lasted to the middle of August. A temperature of 114°, recorded at a number of places, was only 2 degrees below the maximum recorded temperature of the state.

The precipitation was considerably above normal in the western half of the state but below in the eastern half. The effects of high temperature and the deficient rainfall in the eastern half of the state are reflected in the low yield per acre of corn as shown in Fig. 2. Wheat, rye, barley, and oats, which had matured before the beginning of the excessive temperatures, all gave yields above the 1919-1928 averages.

[5] Climatological Data, Nebraska Section, Vol. 35:73-80, 1930.
[6] Climatological Data, Kansas Section, 44:97, 1930.

Bordering States.—In other states bordering those shown on the chart (Fig. 1) similar conditions prevailed. Ohio was reported to have had the driest year on record. The deficiency of rainfall and excess of temperature were more marked in the southern half of the state than in the northern half. Temperatures reached a maximum of 109°. Corn, hay, and pasture crops were greatly reduced, and a general shortage of water for domestic use was felt in the southern half of the state.

In Kentucky, the land received only 51% of its normal precipitation from April to September. The drought began to be noticed there before the end of April, and it steadily expanded and increased in intensity as the season advanced. Heat waves in July broke all records. Growth of crops depended upon short occasional showers which penetrated the soil but slightly. Pastures dried up and farmers were compelled to feed their limited supply of hay or sell their livestock. By August and September large creeks ceased to flow, and springs that had never been known to fail went dry. Many farmers were compelled to haul water long distances for their homes and livestock.

Michigan had less precipitation in 1930 than during any other year since records began in 1887. The drought was confined to the last half of the year. June was a normal month, but less than one inch of rain fell during July and August in much of the southern part of the state.

In Wisconsin, the year was noted for being considerably warmer and much drier than normal. Prolonged periods of drought continued from July 5 to September 25. Of the last 40 years, only 3 have had less precipitation, and temperatures averaged above normal throughout almost the entire year.

In Arkansas, 1930 was a year of extremes in temperature and precipitation. January, with one exception, was the wettest January on record, and May was the wettest May in 40 years. These 2 months furnished for the state as a whole 40% of the total precipitation. The driest June in 40 years was followed by a drier July. Some stations reported only .05 in. of rain for the 2 months and many stations reported under .25 inch. July was the warmest July on record and August recorded a maximum of 114°.

Summary of the Effect of the Drought of 1930

In the per acre yield of corn, all states were below the average of 1919-1928 although Nebraska and Iowa almost equaled that average. In total bushels produced, Nebraska raised 88% more than her average, and Iowa produced 92% of her average. The per acre yield and total production of all the other important corn states were appreciably below their averages. These yields bear close relationships to the character of the seasons in the different states. Nebraska had no appreciable deficiency of precipitation during the critical period of corn growth except in June. The temperature was not excessively high during that period, and evaporation consequently was low. The situation was similar in Iowa, and there was only a slightly less favorable condition in Kansas. Missouri, Illinois, Indiana, and Ohio had deficiencies in precipitation and temperatures above normal for almost all of the months from February to October. In proportion to these variations from normal, the per acre and total yields of corn decreased.

In the yield of wheat in this same drought year, every state represented in this study showed a per acre and total yield higher than the average for the state. January was unseasonably cold, and February unseasonably warm. Precipitation was above normal in April and May, with June dry and warm. These conditions were favorable for the growth and maturation of the wheat. Hence this drought year was a good year for not only wheat but also rye, oats, and barley.

Drought Conditions in 1934

Indiana.[7]—The year 1934 in Indiana was warm and dry. The precipitation for the year was 9.67 in. below normal, and the total was only 0.02 in. above that of 1930, which was the lowest of record. This shortage of precipitation was more marked in the eastern half of the state, especially in the southeastern part where many stations reported the total precipitation as less than one-half the normal.

The 1934 drought in Indiana really began in June of 1933. A shortage in precipitation which began in that month continued through the last half of the year. The precipitation of the three winter months was 3.94 in. below normal for those months and that of the three spring months was 5.47 in. below normal. The total precipitation for the seven months, November to May inclusive, was only 52% of the normal. May had only 1.14 in. of rain, the lowest ever recorded for that month. All stations in the state, except 5 stations for December and 3 for March, reported deficiencies in precipitation for every month from December to May inclusive.

A shortage of soil moisture was apparent at seeding time in the spring. Low precipitation in June and July tended to emphasize the seriousness of the deficiency, especially in the central and northern portions of the state. This deficiency was made more serious by abnormally high temperatures. The average temperature of the summer months, 77.4° F., was the highest on official record. The maximum temperature of 113° equaled the all-time high temperature of 1930. The monthly high temperature records of May, June, and July were equaled. The period of July 20-25 inclusive, when practically all stations in the state reported maximum temperatures of 100° to 113°, established a new record for continuous extreme heat. Though heavy rains occurred during August and September when practically all stations reported amounts above normal, the year ended with a record of precipitation 25% below normal and an appreciable shortage in subsoil moisture.

Corn, wheat, and rye yields per acre were slightly lower than those of 1930. The oat crop, sown in the spring and subjected to the extreme heat, suffered most. The yield, both per acre and total, was only about one-third that of the 1930 drought year crop.

Illinois.[8]—The drought in Illinois, like that in Indiana, began the previous year. All Illinois stations in November, 1933, reported precipitation below normal. All stations, except 5, did the same for Decem-

[7] Climatological Data, Indiana Section, 39:49-52, 1934.
[8] Climatological Data, Illinois Section, 30:39-52, 1934.

ber. During the first 5 months of 1934, except a few stations in March and 3 in April, all stations reported a deficiency each of those months. June and July were both notable for a number of heavy rains. August averaged 0.41 in. above normal rainfall, and in September all stations reported precipitation well above normal.

The year was one of the four warmest years of record for the state. Unusually high temperatures began in May and reached a maximum of 100°. July came within one degree of reaching the all-time high record for the state. August reached the highest temperatures recorded for that month. The number of days with maximum temperatures of 100° or more was two times the number in any previous year of the 55 years of record.

Rainfall occurred in scattered localities in June and over larger areas in July and August. September was one of the wettest of record and tended to increase the yield of corn. The effects, however, of a shortage of soil moisture in the spring, excessive temperatures of summer, and the attacks of pests and insects brought the average yield per acre about 15 bu. below the average for 1919-1928 period. The total yield for the state was a little less than one-half the average. The yield of oats, both per acre and total, was less than one-third that of the average of 1919-1928. The yield of wheat was about 70% of the normal crop.

Missouri.[9]—A dry November and December were the forerunners of the drought in Missouri in 1934. These dry months were followed by 6 other dry months with a precipitation of only 57% of the normal for those months. May was characterized by high temperatures and only 40% of normal precipitation. Drought conditions began to be rather severe by the last of the month. June was the warmest June of record for the state. The deficiency of rain for the previous 8 months and the high temperatures made it one of the hardest months on crops. The oat crop was almost a failure, wheat deteriorated rapidly just before maturity, and corn began to suffer by the end of the month. The hottest June was followed by the hottest July, and a new maximum temperature record of 117° was established. Temperatures were more severe in the northern and western counties than in those of the southeastern part. Precipitation of the month was the second lightest of record of July.

Iowa.[10]—The year in Iowa was the third warmest in 62 years. All months except September and December were warmer than normal. May was the hottest and driest of record. Three days near the end of the month had temperatures of 100° or more and reached a maximum of 111°, which was within 2 degrees of the state's previous all-time high temperature record. The average number of days with temperatures of 100° or higher was 21, which was about two times the number in any previous year. At least 1 station had 42 days with temperatures reaching 100° or more, and a new high-temperature record of 118° was established.

[9] Climatological Data, Missouri Section, 35:62-67, 1934.
[10] Climatological Data, Iowa Section, 45:97-104, 1934.

Precipitation was deficient for 9 successive months, ending with June. July, September, and November were the only months with precipitation above normal. April was the second driest April of record, having only 39% of its normal precipitation. The rainfall of May was only 25% of the normal for the month. The months of June, July, and August, 1934, have had less rainfall than during 17 other summers of the 62 years of record. Good crops have been raised in other years of less rainfall but with lower temperatures. The precipitation of July was slightly above normal but the hot sun and wind evaporated it so rapidly that it had but little value to the crops. The evaporation station at Ames showed an evaporation of 12.11 in. in May, 12.36 in. in June, 10.75 in. in July, and 8.58 in. in August. Crop production ranged from complete failure in some southwestern counties to luxuriant crops in some northeastern counties. The chief cause of crop failure was in the excessive temperature rather than in the amount of rainfall.

Nebraska.[11]—The year 1934 in Nebraska was the warmest and next to the driest on record. The total rainfall was only 14.44 in., which was only 47% of the normal. During the crop season, April to August inclusive, temperatures were unprecedentedly high and the rainfall was low. The temperature averaged over 6% above normal and the precipitation of 7.45 in. was only 47% of normal. The lowest previous record of rainfall for these months was 8.4 in. in 1894. April was warm and had only 22% of normal precipitation. May was the hottest on record, except 1894, and had but 30% of its normal precipitation. June was the third warmest June but had 80% of its normal precipitation. July was a month of uninterrupted heat and drought, the warmest month and driest July on record. There were 15 to 18 days with maximum temperatures of 100° or more. A new absolute maximum of 118° was set at 7 different stations. The rainfall of July, for the state as a whole, was only 35% of the normal, and in some of the southern counties it was only 10% of the normal. "The combination of heat and drought was devastating."[12]

Kansas.[13]—"Record-breaking heat and pronounced shortage of moisture made this one of the most disastrous years for crops ever known in Kansas. It also established a new record for the number of deaths due to excessive heat." The average temperature for the year was the highest since records began, and July was the hottest month ever known in the state. High temperatures, ever increasing in intensity, lasted from about the 19th of June until the middle of August. During the period, temperatures well above 100° were common. New all-time high temperatures were established for both July and August. A temperature of 119° at Lincoln exceeded all previous high temperatures by 3 degrees.

For 5 successive years, Kansas had had deficiencies in precipitation, each year's deficiency being greater than the previous one. In the western part of the state the precipitation was scarcely one-half the normal. This, coupled with the excessively high temperatures, pro-

[11] Climatological Data, Nebraska Section, 39:73-77, 1934.
[12] Ibid., p. 73, 1934.
[13] Climatological Data, Kansas Section, 48:97-103, 1934.

duced devastating conditions on the crops. High temperatures in May caused wheat and oats to head and ripen immaturely. The continued heat and dryness during the remainder of the summer made for a great shortage in the corn crop and brought almost destruction to the pastures and the hay crop. September rains brought relief to the eastern portion of the state, but the western portion continued through the rest of the year with drought and dust storm condition. "Such great deterioration of the corn crop in one month was never known in Missouri. The crop was practically ruined except in some of the southeastern counties and in favored valley locations."[14] Extreme heat and drought continued into the middle of August. Long-standing high temperature records of August were broken in the first 10 days of the month. The second half of the month was cooler and more moist than normal, but the rains came too late to help the corn crop although they aided fall pasture.

Bordering States.—Although 1934 in Ohio was the fifth successive year with precipitation below the 52 year average and the temperature above the average, the per acre yield of wheat was above the 1919-1928 average, and the rye yield was equal to that average. The yield of oats and corn was considerably below the average. These per acre yields reflect the weather conditions of the state. May was dry and hot, and June was the warmest June of record as was also July the hottest month in 52 years. The hot spells were followed in many districts by heavy and destructive storms. These rains brought up the average production of corn but came too late to be of any benefit to the oat crop. This year was one of greater drought in Ohio than was 1930.

In Kentucky, January, February, April, and May had only about one-half their normal precipitation. Rains which came in March and July relieved the situation in some areas of the state. Other rains in July aided the crops but left about one-third of the state in a condition of drought. The drought areas were relieved by other rains in August. Corn and oat yields were about the average, but wheat and rye yields were slightly above the average.

In Arkansas the summer was noted for its high temperature and the long continuation of the heat. The mean temperatures of July and August were the highest in 44 years and the maximum temperature of 116° equaled the all-time high temperature record of 1901. The precipitation from April to October inclusive was 73% of normal for the period, but it was much below normal during June, July, and August. Crops deteriorated noticeably during June and July. It was the intense temperatures rather than the deficiency of moisture which caused the low yields. Streams reached new low-water levels, and stock water became scarce.

The year in Michigan was noted for having all the months of the year below normal in precipitation. The amount of rainfall for the first 8 months was less than for any corresponding period in the history of the state. Drought conditions developed in May and continued through June in most sections. Temperatures of 107° and 108° broke the high temperature records for several stations. The per acre yield of all

[14] Ibid., p. 67, 1934.

cereal crops, except barley, was below the average. Rains in early August and September aided the pasture and potato crop.

Summary

The drought of 1934 is summed up in a bulletin of the Bureau of Agricultural Economics as follows: "The drought of 1934 was the most widespread and devastating of any drought ever experienced in this country. . . . The production of corn for grain, and of barley, oats and grain sorghums in 1934 is 53% of the five-year, 1929-33, averages."[15] Pasture conditions and conditions of the corn crop on September 1, in the areas discussed in this paper are shown to have been less than 35% of normal for the areas lying west of the Missouri river and between 35% and 65% for most of the remaining area. Intense heat was a more important factor than lack of precipitation although the seriousness of the drought was due to a combination of both.

Drought Conditions in 1936

Indiana.[16]—The year 1936 was one of record breaking in Indiana. "All previous official records were broken as to long periods of severe cold in the winter of 1935-36, particularly in January and February; of intense heat during the summer months of July and August; and of sustained drought during a large part of the growing season."[17] Although the average temperature for the state during the year was only slightly above normal, 6 months were exceedingly warm and only 2 months had near average temperatures (Fig. 1). Deficiency of rain began during the winter and continued through spring and into the summer. The maximum deficiency was reached in July in the northern part of the state and in August in the southern part. The effects of the drought conditions were marked by the end of June. This was shown especially by the deterioration of the oat and grass crops. July was noted not only for the low average precipitation, 48% of normal, but also for its long period of unusually high temperatures. Eleven days with temperatures of 100° or higher was the average for the state. Some stations reported as many as 17 days. At some stations there were as many as 13 successive days with maximum temperatures of 100° or higher during July. One station reported 10 successive days with maximum temperatures ranging between 106° and 116°, the latter being a new high temperature record for the state.

The high temperatures of July continued through August. One station reported 20 successive days in August with temperature recordings each day ranging from 100° to 109° and an average maximum for the month of 101°. In the southern half of the state, most stations reported maximum temperatures of 100° or more from 8 to 14 days during the latter half of August. The mean temperature of the month was the highest ever recorded for August in the state.

The drought and excessive temperatures were very severe on the crops in the southern half of the state. Rains during the latter half

[15] Effects of the Drought of 1934 on Feed, Forage and Livestock. October, 1934.
[16] Climatological Data, Indiana Section, 41:49-52, 1936.
[17] Ibid., p. 49, 1936.

of August in the northern part of the state improved the corn and pastures and greatly aided in plowing for fall-sown crops. September was a wet month except in certain portions of the southern part of the state where drought conditions continued. Corn, wheat, and rye yields per acre were almost the same as they were during the drought year of 1930.

Illinois.[18]—Illinois was characterized by an "unparalleled 35-day period of cold in January and February and an unprecedented drought and heat wave in summer."[19] The frequency of zero weather in January and February exceeded that of any year since the winter of 1884-85, and the number of days of 100° or more in July and August exceeded that of any summer. The maximum temperature of 115° equaled that of the previous record of 1901. The state deficiency in precipitation was 6.7 in. The deficiency during the period of April-July was 7.4 in., or 1 in. greater than that of any previous record for those months. Drought effectiveness, a result of low rainfall and intense heat, was the greatest of any of the 7 severe droughts which have occurred during the past 59 years. The yield of corn per acre was less than that of 1930, and about 13 bu. below the average of 1919-1928 period. Rye yield per acre just equaled the average, and wheat was slightly above the average.

Missouri.—Missouri weather records recount three droughts of greater intensity than that of 1930. They occurred in 1901, 1934, and 1936. Of the three the 1901 drought ranked third in intensity. The other two were about equal in intensity and in destructive effects. A comparison of the two is summed up by Roscoe Nunn, Meteorologist at the St. Louis Station, as follows: "Judging by the weather records alone, 1934 was worse in some respects and 1936 worse in others. The rainfall and the water in the principal rivers were less in 1936 than in 1934, but the heat in 1934 averaged for the three summer months a fraction of a degree higher than in 1936. The early onset of the heat was stronger in 1934, when the June temperatures averaged the highest ever known for June. The persistence and duration of the heat were greater in 1936, but June was mostly only moderately warm. The high temperature record of the state was broken twice in 1936, reaching a final maximum of 118°."[20]

In crop yields per acre, corn, wheat, and oat yields were greater in 1936 than in 1934. The corn yield was especially low, both years being less than one-fourth the average in 1934 and less than one-third the average in 1936. The per acre wheat yield in 1936 was slightly above the average for 1919-1928. This was partly due to the fact that the period of intense heat did not begin until the wheat was nearly matured. Severe cold in January and February, together with heavy snows in some sections, protected the wheat plants, conserved the ground moisture, and furthered the growth of wheat in the spring.

Iowa[21].—Iowa's winter of 1936 was noted for its intensity of cold and

[18] Climatological Data, Illinois Section, 41:49-53, 1936.
[19] Ibid., p. 49, 1936.
[20] Climatological Data, Missouri Section, 41:39, 1936.
[21] Climatological Data, Iowa Section, 47:117-127, 1936.

depth of snow cover. A snow fall of 42.9 in. was the greatest in the official records of the state. The period from January 17 to February 21 was probably the most prolonged and severe cold in 117 years (Fig. 1). However, these conditions tended to conserve the soil moisture and protect the fall sown crops. The spring months were favorable for the preparation of the ground for sowing spring crops. May had hardly sufficient rainfall to provide good conditions for the growth of small grains and pasture. June was relatively mild until near the end of the month. On the 25th a prolonged hot period began, which lasted almost without a break until the middle of September. This was probably the longest period of intense heat in 100 years. During July and August all records of high temperatures were broken not only for maximum temperatures but also for the length of the period of intensity. A new high temperature record of 117° was established. The long period of intense heat was also a period of very low rainfall. July approached its lowest record of precipitation. These conditions, especially the prolonged period of intense heat, reduced the per acre corn yield to approximately one-half the average. It is estimated that in total yield it reduced the crop by 235,000,000 bu. This was due chiefly to the heat wave of July 14-31. The cold and snow of winter and the late beginning of the intense heat permitted the wheat crop to reach maturity under favorable conditions. Its yield per acre was above that of the 1919-1928 average and above the average of any year since 1930. Hay and other grain crops harvested in June or early July were not seriously affected by the heat or drought.

Nebraska[22].—For Nebraska, 1936 was the 7th consecutive warm year and the 6th consecutive dry year. February was the coldest month ever recorded in the state and July was the warmest. Precipitation for the year was only 63% of normal and was the least on record except 1894. A warm May with a rainfall 93% of the normal gave an auspicious start to the crop season. However, the 4 following months were far above normal temperatures as reported by practically all stations in the state. June had only about one-half the normal precipitation. July was not only the driest July on record but also the hottest. Maximum temperatures were 100° or more on from 15 to 20 days. The previous maximum for the state, 118°, was reached. July's precipitation was only 18% of normal. August was dry and the warmest August on record. The summer as a whole was the hottest and driest on record. The summer months had only 43% of their normal rainfall.

Crop deterioration which began the latter half of June continued without interruption until September. The drought did not interfere materially with the rye and wheat crops but was disastrous to corn and oats. The per acre yield of corn was less than one-fifth the 1919-1928 average and of oats less than one-half. During September moisture conditions were improved and rye and winter wheat were sown for fall pasturage.

Kansas[23].—1936 was the 5th abnormally dry year since 1930 and the driest in the 50 years of state-wide records. The precipitation for the

[22] Climatological Data, Nebraska Section, 41:73-77, 1936.
[23] Climatological Data, Kansas Section, 50:93-99, 1936.

state as a whole was 8.3 in. below normal and 1.29 in. below that of the previous driest year, 1917. Every station in the state reported temperature averages above normal for every month from May to September inclusive. Practically every station in the state reported deficiencies in precipitation every month except May from February to August inclusive. A new high temperature of 121° was recorded twice in July. In the eastern half, wheat matured under favorable conditions during May and June, but it was greatly damaged by heat in the western half. Corn began to suffer by the last of June and was practically ruined by the end of July which was the second hottest month ever known in the state. August was the hottest and third driest August on record. A plague of grasshoppers added to the disastrous conditions produced by the drought. Rains in September revived the grass, alfalfa, and grain sorghums that had survived the drought and made conditions favorable for fall wheat sowing.

Other States.—In Ohio the drought began in May, which was among the warmest and driest Mays. It was followed by the driest June on record. A heat wave of unusual intensity spread over the state from July 8 to 15 with temperatures reaching 100° or more. A low rainfall and very low humidity prevailed throughout most of the state. August temperatures have been exceeded but three times.

In Kentucky, the drought began in May, was increased by the driest June of record, and was further intensified by intense heat and continued drought during the first half of July. Much damage was done to crops. During the latter half of the month, good rains restored crop conditions in the southern counties. The northern counties were aided by rains in the first half of August, but intense heat and shortage of precipitation brought drought conditions again in the latter part of August.

The year in Wisconsin and Michigan was characterized by unseasonable cold in January and February and unusual heat in July. April and June were below normal temperatures. May, July, and August were above normal. July and August had extended periods of heat waves, and each established new maximum temperature records, 112° for Michigan and 114° for Wisconsin. The average crop production was near the average for each state.

Summary

The three droughts of 1930, 1934, and 1936 were widespread in the central portion of the United States. They decreased in intensity and destructive effects toward the north and south. The year 1930 was relatively moist in the western Great Plains area. In general each drought was more devastating than the preceding one. New high temperature records were established in most of the states. The intensity of the droughts were, in general, proportional to the extremes of high temperature and the length of their period of duration. Excessive evaporation was as important a factor in the deterioration of the crops as was the deficiency in precipitation.

The Mineral Wool Industry of Indiana

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Introduction

Mineral wool is a substance composed of very fine interlaced threads, composed chiefly of calcium silicate, which are glass-like in character and similar in appearance to fibres of wool or cotton. Because of the high percentage of air space for a given volume of wool, it is used extensively for insulating purposes.

Mineral wool may be divided into three classes; rock wool, slag wool, and glass wool. This differentiation is upon the basis of the type of raw materials used in making the mineral wool. Rock wool is made, in most cases, from natural siliceous limestone or calcareous shales. In a few plants other raw materials are used for the manufacture of rock wool. Slag wool is made from blast furnace slags with or without the addition of limestone to temper the charge. Glass wool is made from commercial glass batches.

Early Manufacture of Mineral Wool

Information concerning the beginnings of the mineral wool industry is somewhat meager. Slag wool was made in Germany as early as 1870, according to Lang[1]. The first mineral wool made in the United States was probably made by the Salem Mineral Wool Company of Salem, Virginia. According to a brochure of the National Rock and Slag Wool Association, this company first manufactured mineral wool in 1887 at Salem, Virginia, but the plant was shut down in 1891 and did not operate again. Thus it appears that mineral wool is not a new product but was made in this country at least fifty years ago in much the same form as at present. Only the technique of its production and uses have been changed to meet modern demands.

Rock wool was first made in Indiana at Alexandria in 1897 by Mr. C. C. Hall[2]. Mr. Hall was a chemical engineer for a St. Louis firm which operated a steel plant at Alexandria. He discovered the peculiar qualities of the local rock in his search for a suitable rock for fluxing purposes in the steel plant. His first wool was produced on the premises of the steel company, but when the steel plant was absorbed by one of the steel trusts, he had to move the equipment which he had constructed for the production of rock wool. He then organized, with the aid of local friends, a company known as the Crystal Chemical Company for the purpose of producing rock wool. This plant operated until about 1901 when it was sold to a St. Louis company which was ultimately succeeded by the present General Insulating and Manufacturing Com-

[1] Lang, Herbert, 1923. Designing and Operating a Slag Wool Plant, Chem. and Met. Eng., pp. 365-367.

[2] Thoenen, J. R., 1929. Information Circular No. 6142, Dept. of Commerce, Bureau of Mines.

pany at Alexandria[3]. In 1906, Mr. Hall withdrew from this company and organized the Banner Rock Products Company, which was incorporated in September of 1906 and began operation in January of 1907. This plant, which has been in operation since 1907, is now owned and operated by the Johns-Manville Corporation. These two plants at Alexandria are still the largest producers in the state.

Present Status of Industry

The industry has grown in Indiana from two plants in 1907 to sixteen plants at present (1937). One of the sixteen plants is not producing at the present because of litigation over the ownership of the plant. The location of these sixteen plants is shown in Fig. 1. All of the plants except the one at East Chicago produce rock wool. The plant at East Chicago produces slag wool from lead slag. The plants vary in size from one to fifteen cupola installations. In all there are 61 cupolas installed in the state. Twenty-nine of the cupolas are in the two plants at Alexandria. There are fourteen cupolas in the three plants at Wabash. Thus Alexandria and Wabash have between them about three-fourths of the cupolas which are producing mineral wool in Indiana. The following table gives the name, location, date that plant began operation under present name, and the number of cupolas in each plant.

Name of Company	Location	Date	Cupolas
Banner Rock Products	Alexandria	1907	15
General Insulating and Manufacturing Co.	Alexandria	1912	14
Union Rock Wool Corp.	Wabash	1921	3
Weber Insulations Inc.	East Chicago	1927	2
Standard Rock Wool Inc.	Yorktown	1930	2
Salem Lime and Stone Co.	Salem	1931	1
Standard Lime and Stone Co.	Wabash	1931	5
Indiana State Farm	Putnamville	1932	1
American Rock Wool Corp.	Wabash	1934	6
Zier Products Co.	New Albany	1934	1
National Rock Wool Sales Co.	Lagro	1935	3
Western Rock Wool Co.	Huntington	1935	2
Mineral Felt Co.	Campbellsburg	1935	1
Ellis Fish Inc.	Bedford	1936	2
North Vernon Rock Wool Co.	North Vernon	1937	1
Superior Rock Wool Co.	Lagro	1937	2

The plant at Campbellsburg is not at present producing wool because the ownership of the plant is now in litigation. The cupola at the State Farm at Putnamville can hardly be considered a commercial plant because the output of this cupola is small and is limited to supplying the needs of the State Farm and other state institutions.

It will be noted from the table above that thirteen of the sixteen plants in Indiana have been organized within the last ten years. Several

[3] The writer wishes to acknowledge his appreciation of the courtesy shown by the General Insulating and Manufacturing Company in furnishing him with photographic material for this article and particularly to Messrs. D. W. Burnett and M. E. Mann for much very helpful information regarding details of plant procedure.

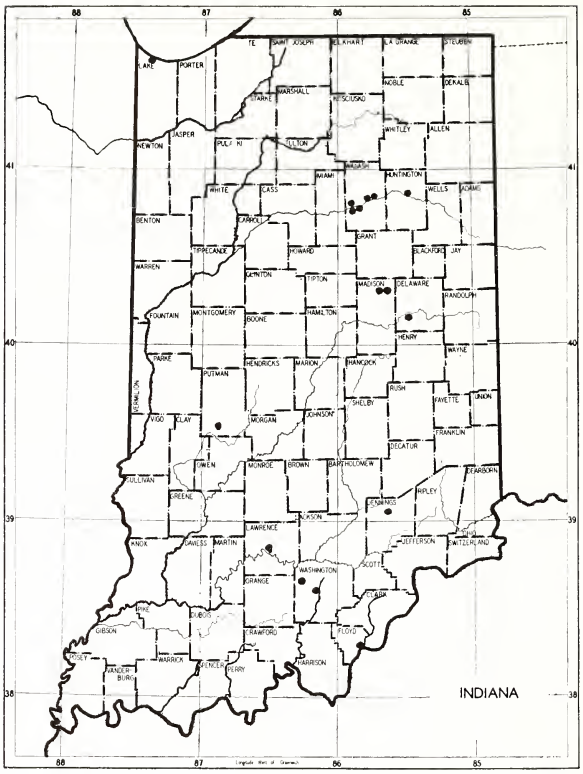

Fig. 1. Location of Mineral Wool plants in Indiana.

of the cupolas in the older plants have been installed within this decade also. The plants at Yorktown and Campbellsburg began operation at earlier dates than those given but have undergone reorganization at later dates.

This growth of the industry within the last ten years is typical of the industry nationally as well as within Indiana. In 1929, there were only eight producers of mineral wool in the United States. Two of these were in Indiana, and there was one each in California, Illinois, Michigan, New Jersey, Ohio, and Wisconsin. At the present time there are about fifty-six plants in the United States which manufacture mineral wool, and in addition there are nine companies which sell mineral wool products on the market but do not manufacture them themselves. The exact number of plants is difficult to ascertain because new plants are opening and some old ones closing down. The distribution of these fifty-six plants is shown in Fig. 2. Indiana ranks first in the list with sixteen plants, followed by Ohio with nine; Illinois and New Jersey with six each; Pennsylvania and California with three each; New York, Michigan, and Utah with two each; and Wisconsin, Virginia, Missouri, Texas, Tennessee, Iowa, and West Virginia with one plant each.

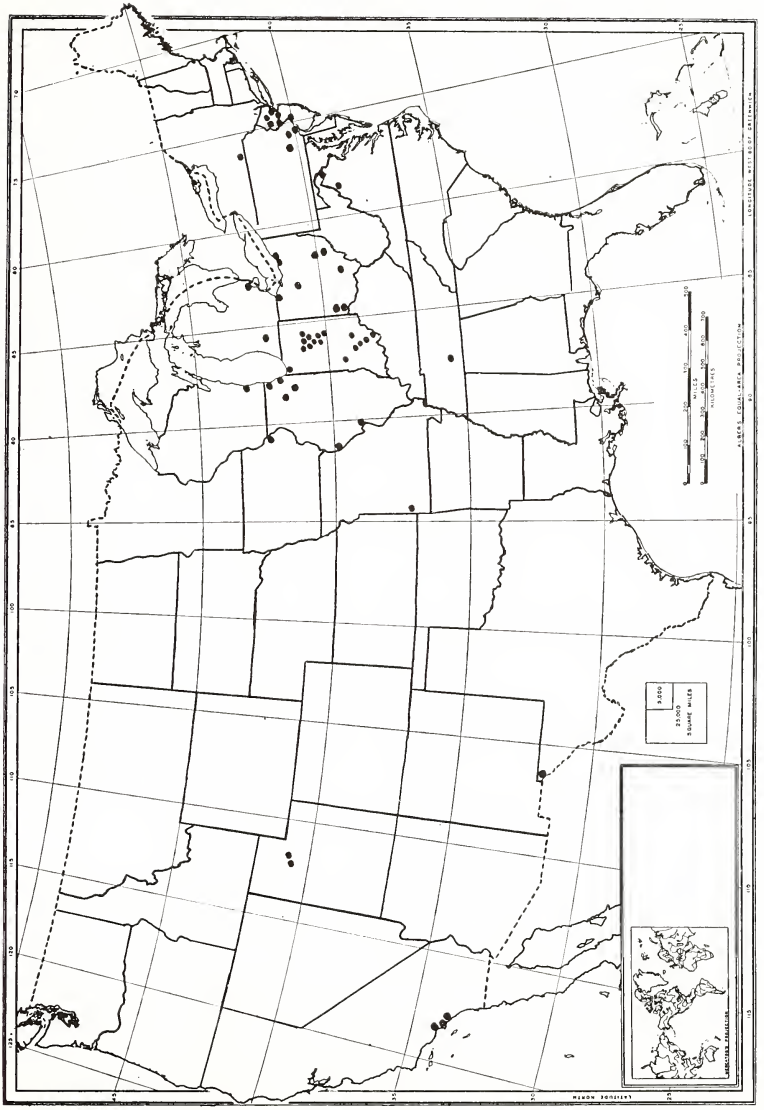

Fig. 2. Distribution of Mineral Wool plants in United States.

Indiana still holds first rank in the manufacture of mineral wool but is relatively slightly less important than it was ten years ago. There has been a rather noticeable tendency toward decentralization of the industry apparent within recent years. While Indiana, Ohio, and Illinois have more than half of the plants, there have been several new plants go up in the east and west within the last few years. This probably is due to the effect of freight costs upon the mineral wool. Mineral wool is a rather bulky product. A standard box car will accommodate only twelve tons of wool. This makes the freight costs high. The importance of freight costs is shown by the following table of freight costs of wool from Alexandria:

To Chicago	$ 4.80 per ton
To Cleveland	5.80 per ton
To Baltimore	9.00 per ton
To New York	10.00 per ton
To Birmingham	19.40 per ton
To Los Angeles	52.50 per ton

It is easy to see why three plants have gone up around Los Angeles within the last few years.

Another item that may have some effect upon the location of new plants is the nearness to fuel. Coke is the chief fuel used in the cupolas. Indiana does not have any good coking coal within the state, so the coke has to be shipped in at some considerable expense.

Raw Materials Used

Most of the mineral wool made in Indiana is rock wool. As stated above, fifteen of the sixteen plants manufacture rock wool. The plant at East Chicago used lead slag for the manufacture of wool. However, the type of raw materials used varies considerably throughout the state. The plants in northeastern Indiana all manufacture rock wool from a calcareous shale or argillaceous limestone known to the geologist as the *Mississinewa Shale*. Small amounts of local limestones are usually added as flux. This *Mississinewa Shale* is the so-called "fuzz rock" of the quarrymen. It has about the following analysis at South Wabash[4], which is fairly typical for northeastern Indiana.

SiO_2	30.89
Al_2O_3	13.21
Fe_2O_3	5.69
$CaCO_3$	28.03
$MgCO_3$	14.32
TiO_2	0.68
H_2O etc.	5.61

While analyses of the *Mississinewa Shale* show slight variations in the percentages of the various constituents, the formation is remarkably similar in composition over considerable areas. There seems to be then very little basis for the claims made by some manufacturers of rock wool in northeastern Indiana that their wool rock is unique in

[4] Cumings, E. R., and Shrock, R. R. The Geology of the Silurian Rocks of northern Indiana, Dept. of Conservation, Division of Geology, Publication No. 75, p. 57.

physical and chemical properties. There is a rather extensive area comprising parts of Wabash, Huntington, Grant, Madison, and Delaware counties, where the *Mississinewa Shale* may be found in outcrops or at no great depths beneath the surface. The mineral wool plants at Wabash, Huntington, Lagro, Yorktown, and Alexandria all use the *Mississinewa Shale* as their basic material. The flux rock used with it varies locally.

There are five strips of land in this area where the *Mississinewa Shale* outcrops. These are (1) along the Wabash River from a few miles above Huntington downstream to a point a few miles below Wabash, (2) along the Salamonie River from near Warren in southern Huntington County down the Salamonie to the point of its junction with the Wabash near Lagro, (3) along the Mississinewa River from Marion downstream to a point a short distance below Red Bridge, (4) along White River from a short distance above Yorktown downstream to about the western boundary of Madison County, and (5) along Pipe Creek from Alexandria southwestward nearly to its junction with White River. No doubt there are several other areas within this general region where the *Mississinewa Shale* is near enough the surface that the overburden could be removed without too great expense. Certainly there are enough possible locations for quarries within this area to take care of the needs of this industry for many years to come.

The rock wool plants in the southern part of the state use a variety of raw materials for the manufacture of their wool. The following table indicates the location of the plants and the raw materials used.

Ellis Fish Inc. (Bedford)	*Salem* ls. and *Borden* sh.
North Vernon Rock Wool Co. (North Vernon)	*Devonian* ls. and top soil
Mineral Felt Co. (Campbellsburg)	*Harrodsburg* ls., *Chester* ss.
Salem Lime and Stone Co. (Salem)	*Salem* ls. and clay
Zier Products Co. (New Albany)	River gravels and limestone
Indiana State Farm (Putnamville)	*Chester* (?) ls. and sh.

It thus appears that rock wool can be made from a great variety of raw materials. The *Mississinewa Shale* of northeastern Indiana has nearly the proper ratio of silica and lime, but almost any raw materials may be used provided they are combined in such proportions as to give the proper ratio between these two major constituents. That this mixture of materials can be done successfully is demonstrated by the plants in southern Indiana. The Bedford plant uses the waste limestone from the mills in Bedford and mixes it with shale trucked in from Rivervale, about twelve miles south of Bedford. The plant at North Vernon is a very interesting one because it uses a local limestone; which has been quarried north of town for many years for road metal, and mixes with it top soil from around the plant. The mixture makes a very nice looking rock wool. The plant at Campbellsburg uses local *Harrodsburg* limestone and a *Chester* sandstone trucked in from near Orleans. The plant at Salem uses some of the oolitic phase of the *Salem* limestone and mixes with it some of the so-called "bastard stone" from the *Salem* limestone and clay from the top soil. Perhaps

the most interesting plant from the standpoint of raw materials used is the one at New Albany, where Mr. Zier is making rock wool from a mixture of river gravels and local limestone. He is contemplating the construction of a new unit which would burn oil instead of coke and use top soil and limestone in the same manner as is being done at North Vernon.

When it is apparent that mineral wool can be made from such a variety of materials, including of course slag and glass wools, it seems rather obvious that no company is going to be able to get anything like a monopoly upon the raw materials from which mineral wool is made. The difference between success and failure seems to lie more in efficiency in manufacturing and marketing rather than in control of raw materials.

Quarrying Practice

In practically all of the plants the quarrying methods are the ordinary ones used in quarrying stone for use as road metal. In some of the smaller plants the loading is done by hand, but in the larger plants the steam shovel is used. In several of the plants part of the raw materials is trucked some distance to the plant. Probably the greatest distance that any material is trucked is at Bedford where shale is trucked twelve miles from Rivervale.

Manufacturing Methods

Both rock and slag wool are melted in cupolas. The ordinary rock wool cupola is a vertical steel cylinder which is generally water-jacketed. It is roughly 4 or 5 feet in diameter and 8 to 10 feet high. The charge in the cupola consists of alternate layers of coke and rock or slag in the ratio of about one part of coke to two to four parts of rock. Blowing tuyeres are placed about two feet above the bottom of the cupola. These average about eight in number. Air is blown through the tuyeres by a blower fan at low pressure. The fusion temperature in the cupola varies considerably, depending upon the material used. It ranges from about 2400° to 2800° Fahrenheit. The bottom of the cupola has drop doors to facilitate the cleaning of the cupola. This has to be done on the average about once weekly. The capacity of the cupola varies considerably with the individual plants. It ranges from 500 to 1500 pounds of wool per cupola per hour. The better installations average 800 to 1000 pounds per hour. In some plants the proportioning of the charge in the cupola is done by counting shovels of each type of material; in other plants the proportioning is done entirely by weight.

Blowing Wool

The molten material in the cupola issues in a small stream from a hole at the bottom of the cupola. As the molten slag falls from the hole at the bottom of the cupola, it is broken by a steam or air jet blow at pressures varying from 80 to 150 pounds and is broken into minute balls or shot which, while still molten, are propelled rapidly through the air. This comet-like propulsion through the air draws them

out into fibres or threads. Some of the material may not be drawn out into fine fibres, and this forms the so-called "shot" in the wool. The "shot" occurs as small globular beads of glass-like texture. The formation of shot seems to be related to the composition of the charge and the force of the air or steam. In general, it seems more practical to discard the "shot" after formation rather than to attempt to prevent its formation. The "shot" is separated from the wool fibres by passing the wool through a machine very similar to a grain separator.

Fig. 3. Blowing rock wool from cupola into wool room. (Courtesy of General Insulating & Manufacturing Co.)

Practice varies as to the form and shape of the steam or air jet blower. Much of the secrecy which is associated with the production of mineral wool relates to the methods of blowing the wool and of injecting certain materials into the wool to give it binding qualities. The person or concern contemplating entering the mineral wool industry runs into the patent problem at this point. This is one thing that may to some extent tend to prevent too rapid a spread of mineral wool production.

Not all slags will make wool. One too high in iron will blow into shot without any trace of fibres. Slags too rich in alkaline earths will

blow into short wool or even dust. To produce a long-fibred wool a slag is required that has a prolonged period of plasticity or viscosity. There should be a wide range of temperature between softening and complete fusion. Glass best illustrates this phenomenon, and this fact helps to explain why very excellent wool can be made from glass batches. Some slags will make light-colored wools and some make dark-colored wools. Tradition has rather required that the wool be light-colored, which necessitates the slag being nearly free of iron. However, since mineral wool is usually placed in covered places, it seems that color is of little moment. The wool may be black as far as its value for insulation is concerned. The insulational value of the wool depends upon dead air cells, not upon its color. Incidentally, the addition of binding material must diminish the efficiency of the wool for insulation purposes because the binding material eliminates air space. Insulation in the powdered form is thus inferior to the fibre form, although it is more easily shaped.

The wool is blown from the cupola by the steam or air jet into a so-called wool room. In the early days of the industry, the wool was collected and bagged by hand. Two rooms usually were used so that one could be emptied while the other was being filled. In the modern plants the wool from the cupola is carried on an endless conveyor and goes through a set of rollers from which it emerges in rolls. These rolls may then be worked upon into the various types of products made by the plant. The smaller plants generally make chiefly loose or granulated wool, while the larger plants make a variety of products.

Mineral Wool Products

In the early days of the industry most of the mineral wool produced was either what is known as loose or granulated wool. The term loose or bulk wool is applied to the direct product of the cupola. Mineral wool is still used in that form where a loose insulating material is needed. The loose wool may be run through a machine which separates the "shot" from the fibres. This results in a short fibre which is "shot-free" and which goes by the name of granulated wool. This is widely used where a loose insulating material is needed. It is packed in standard bags weighing 35 pounds. The granulated wool can be poured or blown into spaces.

Mineral wool may be fabricated in various forms to meet particular needs. Some of the more common forms are: (1) Blankets—Blankets are made by placing the wool between two wire nettings. They may be made in various sizes and thicknesses, and in newer buildings may be placed directly on or between the studding. Blankets are also used for boiler and oven insulation. (2) Rolls—The wool is made into rolls much like rolls of cotton or wool and can be used either for the same purposes as loose wool or as blanketing material. (3) Blocks—The wool is pressed into blocks of varying size. The thickness seldom exceeds 2½ inches. Blocks are used for oven insulation, heating and air conditioning ducts, hot air furnaces, and other light heated equipment. (4) Bats—Bats are similar in shape to blocks but are of greater thickness and are used where thicker insulation is needed than is provided by blocks.

Fig. 4. Mineral Wool products. Upper, loose wool; lower, granulated wool. (Courtesy of General Insulating & Manufacturing Co.)

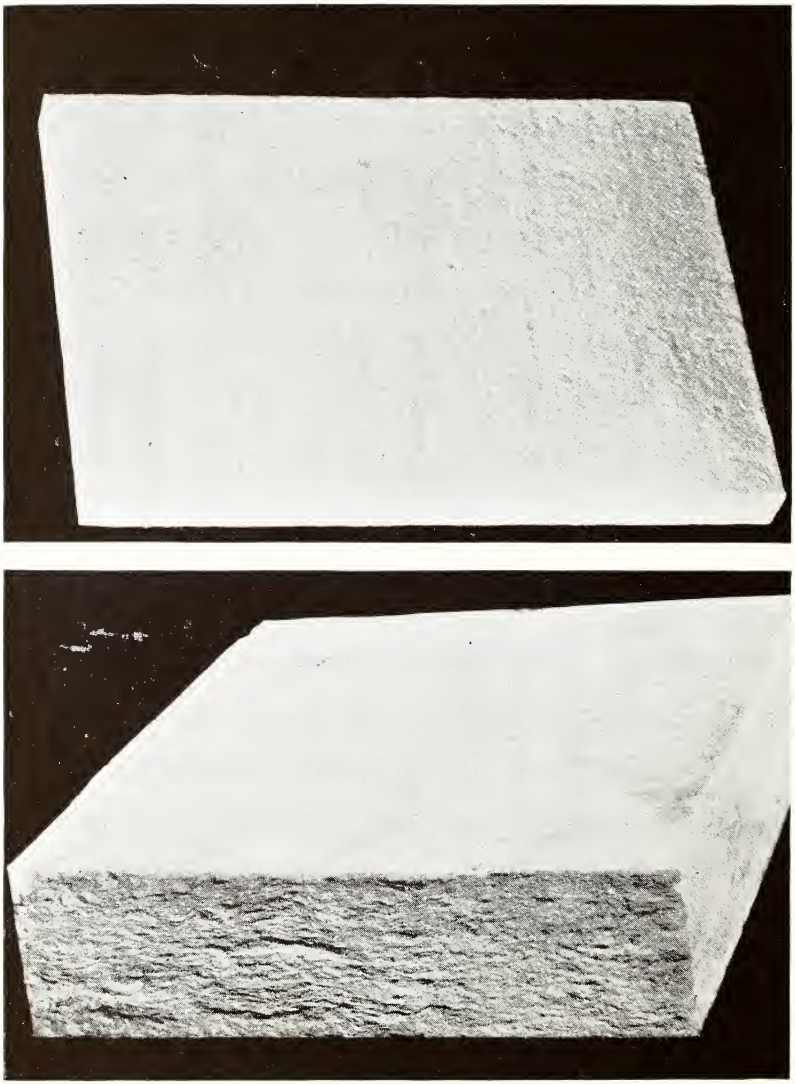

Fig. 5. Mineral Wool products. Upper, block; lower, bat. (Courtesy of General Insulating & Manufacturing Co.)

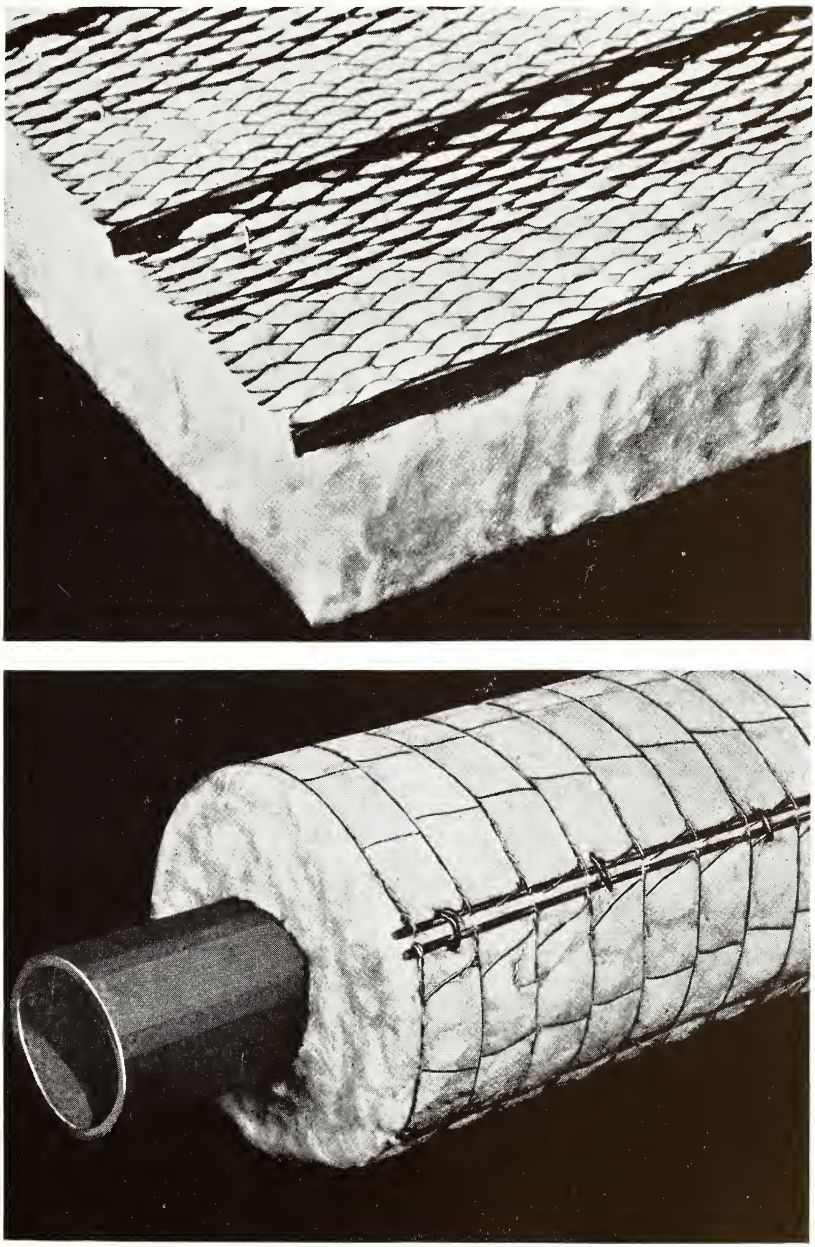

Fig. 6. Mineral Wool products. Upper, blanket; lower, pipe covering. (Courtesy General Insulating & Manufacturing Co.)

In addition to the above-mentioned common forms, mineral wool is also made into pipe covering, cork board, sound-absorbing blankets, pads, panels, felt, rock wool cement, plaster, and brick. Thus it is apparent that mineral wool has a great variety of forms and uses for both sound and heat insulation.

Value of Mineral Wool

Accurate data on the value of mineral wool produced in the state and nation are difficult to obtain because the producers of mineral wool are very secretive as to the amount of wool which they produce. This secretiveness is probably due in part to the fact that the industry is a relatively new one, which is expanding rapidly, and that each manufacturer is jealous of his rank in the industry. However, some information is available from the Biennial Census Reports. These reports estimate that the value of all mineral wool produced in the United States in 1900 was slightly over $60,000, about one-third of which was slag wool. No glass wool was produced in this country then. Since 1900, the value of mineral wool products has steadily increased, except for a few years during the worst of the depression, until in 1935 the value of the products of the industry was estimated at $7,672,096. Estimates for 1936 indicate a production value nearly double that for 1935. The following table indicates the rate of growth of the industry.

Year	Value of Products
1900	$ 60,320
1910	84,012
1929	2,377,324
1931	2,873,230
1933	1,714,171
1935	7,672,096
1936	14,000,000 (estimate)

Most of the rapid growth of the industry has been in the last ten years.

Statistics are not available on the value of the mineral wool produced by states. A rough approximation of the value of the mineral wool produced in Indiana may be obtained by comparing the number of plants in Indiana with the number in the entire country. There are sixteen plants in Indiana which are producing mineral wool. There are, according to the best information available, fifty-six plants in the United States which produce mineral wool. Indiana, therefore, has about 28-29% of the plants operating in the production of mineral wool. This would indicate for 1935 a value of wool produced of slightly over $2,000,000 dollars. If the estimates for 1936 are nearly correct, the value of wool produced in 1936 in Indiana should have been around $4,000,000.

Indiana is still the leading state in the production of mineral wool, but is relatively less important than in the early days of the industry. In 1929, four of the eight producers of mineral wool were in Indiana. In 1935, eleven of thirty-eight producing companies were in Indiana and in 1937, sixteen of fifty-six producing companies were in Indiana.

In 1931, "American Builder and Building Age" forecast that the

mineral wool industry would very likely in time become a $100,000,000 industry. The rapid growth of the industry within the last ten years seems to suggest that it bids fair to become one of our leading mineral industries. If Indiana can continue to hold its own in the production of mineral wool as well as it has for the last ten years, the value of the mineral wool produced in the state may reach $15,000,000 or $20,000,000 eventually. Even at the present status of production, the value of mineral wool produced in the state is as great as the value of the famous oolitic limestone which is so widely used as a building stone. The Minerals Yearbook gives the value of the limestone in the Indiana Oolitic district for 1935 at $1,854,245. This is about the same as the estimated value of the mineral wool produced in Indiana for that year. Indiana may then look forward with increased assurance toward contributing in a large measure toward the better homes of the future through her limestone and mineral wool.

Some Observed Effects of Certain Atmospheric Variations

A. V. Lott, Sellersburg

The series of severe and devastating droughts that have affected much of the United States, Canada, and some other parts of the world during the last decade has emphasized the need of a better understanding of the conditions which make such calamities possible. Man can hardly hope that he will ever be able to prevent the actual occurrence of such abnormalities of the weather, but, if he can gain a better understanding of their causes and of the conditions necessary for their recurrence, he may possibly be able to recognize their approach in time to make some preparations for rendering their effects a little less severe.

This possibility has prompted the writer to make an intensive study of the atmospheric conditions which prevail during such periods of abnormal weather. Daily observations of atmospheric conditions were made during a period of more than six years, and these observations were compared with the weather charts published daily by the United States Weather Bureau. Observations made by others were also checked with the daily weather charts. Some knowledge has been gained. Some observations were made that were not altogether in agreement with good meteorological theory. In such cases the observations were carefully checked and rechecked in order to make sure that there were no mistakes due to faulty observation. When these unusual conditions occurred again, they were carefully observed and the resulting weather noted. This practice eventually resulted in certain interpretations and conclusions which the writer believes to be new and of possible value in weather forecasting.

It is the purpose of this paper to call attention to some of the observations that have been made, to explain the interpretations that have been given, to state the conclusions reached, and to show how these interpretations and conclusions, if accurate, may be of considerable value in determining the long range weather trends.

Those desiring a more complete knowledge of the many and various effects of certain atmospheric conditions and variations are referred to Dexter[1], Huntington[2], and others who have discussed various phases of the matter. This discussion will be confined to variations in the velocity of the general circulation, their effects, and certain observations connected therewith.

That variations in the velocity of the general circulation actually occur is clearly indicated by the irregular variation in the speed of the migratory pressure formations as they are carried along by the general air movements. Irregular variations have been observed ranging from a low value of 2 miles per hour to a high value of 66 miles per hour during January, and values ranging upward to 39 miles per hour in

[1] Dexter, Edwin G., 1904. Weather influences. New York.
[2] Huntington, Ellsworth, 1915. Civilization and climate. New Haven.

July[3]. These movements show that the general circulation is usually more active and moves more rapidly in winter than in summer. The more rapid winter movement is usually attributed to the increase in the poleward temperature gradient resulting from the lower winter temperatures in middle and lower latitudes. That explanation, however, is probably not the true one because the winter variations are very irregular, and the observed variations do not correspond to the changes in temperature required by the theory. In other words, the more rapid circulation does not occur when temperatures are lowest in middle and lower latitudes, nor does the more sluggish circulation occur when the temperatures are higher, but just the opposite. The writer has also observed that the general air movements may be very sluggish during the winter months and then become more active as summer approaches. These irregular variations in velocity seem to have a peculiar effect upon the form and the direction of movement of the migratory pressure formations and a somewhat similar effect upon the stationary pressure areas.

It was first observed that the great masses of cold air which form during the winter months at points near or above the Arctic Circle sometimes follow a northern route which leads southeastward and eastward toward Hudson's Bay. Sometimes they follow what may be called a middle route which leads southeastward across the Lake Region and into the Ohio Valley, and thence eastward to the coast. At other times the masses of cold air follow a western track southward over the Rocky Mountains and Great Plains toward Mexico and the Gulf Coast. Further observations showed that the northern route was usually followed during periods when the pressure formations were moving rapidly eastward. The middle route was followed during periods when the pressure formations were moving more slowly eastward, and the western track was followed when the atmospheric movements were usually very sluggish. These observations seem to indicate that there may be a very close relationship between the velocity of the general circulation and the tracks which are followed by Arctic air masses.

This relationship can be more easily understood if consideration is given to the fundamental principle which causes all moving masses that are not rigid to become elongated in the direction of their most rapid motion. The truth of this principle is very evident even in the case of semi-rigid masses, such as glaciers, or ice sheets, the moving masses of ice becoming elongated in the direction of their most rapid motion.

All masses of moving air must conform to this fundamental principle. If a mass of cold air appears over Alaska or northern Canada, it may possibly suffer a slight development westward toward a region of low pressure, but it cannot be carried westward against the planetary wind system. The air mass may follow any one of three courses. It may move eastward with the movements of the general circulation, or it may move southward, or it may move in a direction that is some combination of these two movements. If the eastward drift of the atmosphere is very rapid at the time, the air mass may be expected

[3] Milham, W. I., 1912. Meteorology. New York.

to develop in the direction of its most rapid motion; that is, the air mass will probably follow the northern route eastward toward Hudson's Bay. If the general atmosphere is moving less rapidly eastward, the air mass may be able to move southward just about as easily as it can move eastward. In such cases the actual movement is usually a combination of the two movements; that is, the air mass moves southeastward and follows the middle route. However, if the eastward drift of the atmosphere is very sluggish, the air mass can develop southward more easily than it can move eastward. The mass obeys the fundamental principle and extends its long axis in the direction of its most rapid motion; that is, it develops southward along the western track toward Mexico and the Gulf Coast.

This suggestion, that the tracks of Arctic air masses may be determined largely by the velocity of the general circulation at the time of movement, is believed to be new. The writer has endeavored to put it to the hardest test that can possibly be given, that of actually forecasting the particular region to be affected by the cold wave, even before the cold air mass has left the Arctic Circle. The results have been very encouraging. Some errors have been made. The greatest errors occurred during periods when the circulation was subject to irregular variations of short period, and the greatest successes have occurred during periods when the short period variations were absent.

The irregular variations of short period may cause the cold air mass to shift from one track to another during the forecast period. Two common examples have been observed quite frequently. If the general eastward movement of the atmosphere is moderately rapid, the cold air mass may be expected to move eastward along the northern route, but if the eastward movement should be retarded during the forecast period, the air mass will obey the fundamental principle and develop southeastward or southward, bringing severe temperatures to a region that might have escaped had the same rapid movement continued for a day or two longer. If the eastward drift is sluggish at the time when the forecast is made, the forecaster may have the reasonable assurance that the mass of cold air will follow the western track southward; but, if the eastward movement should become more rapid during the forecast period, the air mass will develop more rapidly eastward and thus cause the forecast to be more or less in error.

These variations of short period cause the work of the forecaster to become especially difficult, but, if the variations are absent, the circulation may move at a fairly uniform velocity for periods ranging upward to several months. Such long periods with little fluctuation have made it possible for the effects of velocity upon the form and direction of pressure formations to be detected and traced.

Charts of world pressures show areas of high atmospheric pressure over the oceans during the summer months. Pressure charts for the months of January and July may be found in physical geographies, while Bartholomew's Meteorological Atlas[4] shows pressure conditions for each month of the year. It should be understood that these charts show only mean, or average pressures. They do not show pressure

[4] Bartholomew, J. G., and Herbertson, A. J., 1899. Bartholomew's Physical Atlas. Volume 3. Edinburgh.

conditions when the circulation is very rapid nor when it is very sluggish. However, a study of oceanic pressures during extended periods of both rapid and sluggish circulation shows that the velocity of the general circulation seems to affect these stationary areas in practically the same way that it affects the migratory pressure formations; that is, the pressure areas develop in the direction of their most rapid motion.

Changes in the velocity of the general circulation seem to cause certain changes in the form and position of the oceanic anticyclones. These changes are illustrated in Figure 1. The anticyclone *A* represents the form and position of the oceanic pressure area during periods of moderately sluggish circulation. Note that the major axis of the anticyclone lies in a southwest to northeast direction. This is due to the fact that the general air movement is from west to east in the higher latitudes, and from east to west in the lower latitudes, in accordance with the planetary wind system. A full discussion of the planetary winds may be found in most of the general discussions of meterology. These winds cause the anticyclone to develop toward the east in the higher latitudes and toward the west in the lower latitudes. Hence its major axis lies in a southwest to northeast direction.

A moderate increase in the velocity of the general circulation causes the anticyclone to develop more rapidly toward the east in the higher latitudes and toward the west in the lower latitudes. This seems to cause some change in the form and position of the anticyclone, the major axis of the pressure area becoming extended in the direction of its most rapid motion. This change is shown in the anticyclone marked *B* in the illustration. A further increase in the velocity of the general circulation causes a further rapid development eastward in the higher latitudes and westward in the lower latitudes. This causes a further change in the form and position of the anticyclone, as shown in formation *C* in the illustration. Note particularly how the anticyclone tends to assume a horizontal position as the circulation increases in velocity. When these stationary anticyclones lie more nearly in a horizontal position they appear on the pressure charts as belts of increased pressure that completely encircle the earth.

Clockwise winds prevail around an anticyclone in the northern hemisphere. This wind movement is shown in the illustration by the arrows which accompany each formation. Note particularly the changes in the direction of the prevailing winds as the anticyclone changes in form and position. Similar changes in the direction of the prevailing winds that have continued throughout an extended period have been observed and reported by Ray. Certain changes in the direction of the trade winds over the North Atlantic Ocean are shown in percentages in the following table[5].

	Northeast	East	Southeast	South
1905-1920	20	35	26	10
1921-1929	6	55	16	15

Note particularly the change from northeast, in the period from 1905 to 1920, to east in the period from 1921 to 1929. Ray also states that similar changes occurred in the direction of the trade winds over

[5] Ray, C. L., 1933. The North Atlantic trade winds. Mo. Wea. Rev. 61:261-264.

the Pacific Ocean at approximately the same time. The fact that similar changes occurred over both oceans at approximately the same time suggests that the cause must be found in some factor that affects the general circulation. Ray reaches the conclusion that the change may be due to a northward displacement of the oceanic anticyclone. That conclusion is probably correct. The writer suggests that the northward displacement of the anticyclone may be due to an increase in the velocity of the general circulation. Such a displacement is shown in Figure 1. Particular attention should be given to the fact that the southern part of the anticyclone is gradually displaced into the higher latitudes as the circulation increases in velocity. It should also be noted that a similar displacement into the lower latitudes occurs as the circulation decreases in velocity. These changes in the form and position of the oceanic anticyclones are of the greatest importance because of their influence upon summer weather conditions over continental areas.

A further study of the three formations shown in Figure 1 reveals the fact that the major axis of the anticyclone shifts, or rotates in a clockwise direction as the circulation increases in velocity, and in an opposite, or anticlockwise direction as the circulation decreases in velocity. A question may be raised regarding the actuality of this movement. Do the major axes really rotate in the manner suggested? Strong evidence which seems to indicate an actual rotation of the axes of anticyclonic areas is found in the tracks followed by cyclonic storms. These cyclonic areas, or lows, move around the anticyclone rather than through it. The low cannot pass through the high pressure area unless a break or gap occurs in the pressure ridge. Therefore the direction taken by the moving cyclone is determined largely by the major axis of the adjoining anticyclonic area. If the major axis lies in an east-west direction, any cyclone forming west or north of the anticyclonic area will move rather rapidly in a west to east direction along the northern side of the elongated anticyclonic area. Any tropical cyclones which form on its southern side must either break through some weak spot in the pressure ridge or be carried around its western end. They are usually carried westward by the prevailing winds, some of them curving toward the northeast at points far west of the normal position, while others blow themselves out over land areas without changing their course to any considerable extent. If the circulation is sluggish and the major axis of the anticyclonic lies more nearly in a southwest to northeast, or a south to north direction, the cyclones which move around it must also move more nearly in a south to north direction. The tropical cyclones or hurricanes may very easily pass around the anticyclonic area without causing destructive winds over any part of the continent. This condition prevailed during the hurricane season of 1937 when the storms moved more generally in a south to north direction. The movements from east to west without recurving were observed quite frequently during the hurricane season of 1936.

These observed movements of cyclonic storms seem to indicate that the major axes of the oceanic anticyclonic areas actually rotate in the manner described. When the matter becomes more fully understood,

and accurate data on the velocity of the general circulation have been obtained, weather forecasters should be able to determine the probable tracks of tropical cyclones even before the hurricane season begins. If the circulation is sluggish, the forecaster may have the reasonable assurance that the cyclones will move toward the north or northeast without striking the continent. If the circulation is rapid to very rapid, some storms of considerable intensity are practically certain to pass over the mainland and may cause much destruction. These hurricane tracks may be more clearly understood if careful study is given to the formations shown in Figure 1.

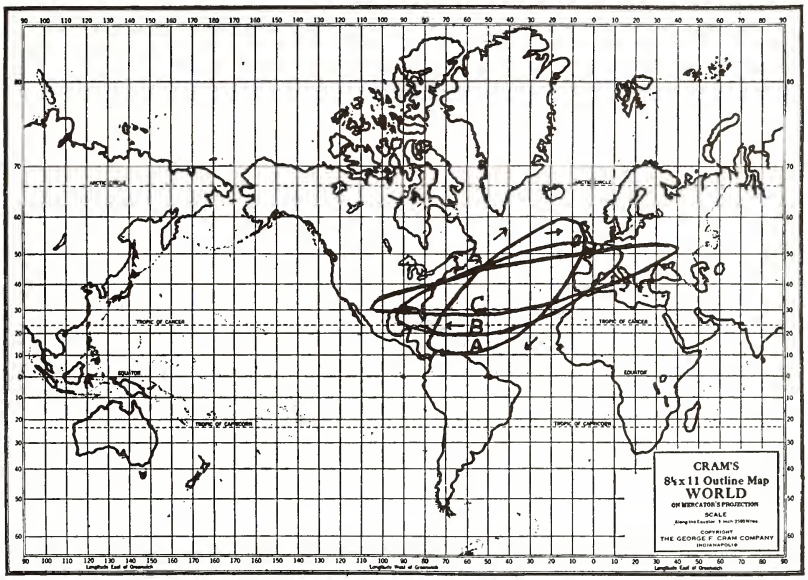

Fig. 1. Changes in the form and position of the pressure area as the circulation varies in velocity. The arrows show the wind direction in some parts of the pressure area.

When the atmosphere is moving eastward at or near its normal velocity for this particular age of the earth's history, the western end of the Atlantic anticyclone extends inland over the southeastern states. This inland extension is shown in all pressure charts of average conditions. These charts may be found in many physical geographies and in Bartholomew's Meteorological Atlas, which has been cited earlier in this discussion. The normal extension of the anticyclone over the southeastern states is shown in Figure 2. An increase in the velocity of the general circulation causes this anticyclone to shift its position slightly and causes it to become more elongated in an east-west direction. The normal inland extension of the oceanic pressure area develops farther inland and forms a ridge of increased pressure over the southern states and the Gulf of Mexico, which effectually prevents all inflow of moist air from the Gulf. This pressure condition is illustrated in formation *C* of Figure 1.

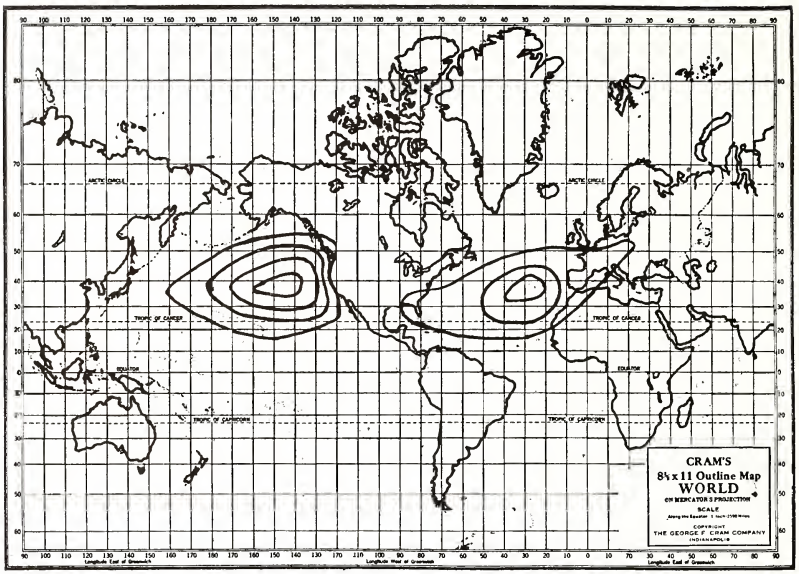

Fig. 2. The average position of the oceanic areas of increased pressure, as they are shown on the average pressure charts.

The same rapid circulation which causes the east-west elongation of the Atlantic anticyclone also causes a similar elongation of the Pacific pressure area, which forms an extension eastward across the mountains. This inland extension is not shown on the pressure charts, due to high temperatures and reductions to sea level, but its existence is revealed by the stagnant low pressure trough in midwestern sections, and by the tracks of cyclones which move around the inland extension on its northern side. The inland extensions of the two pressure areas tend to unite in the formation of a pressure ridge across the United States, with a shallow pressure trough somewhere in the interior between the inland extensions of the two pressure areas.

This particular type of pressure conditions causes the most severe drought to prevail over widely extended areas in the United States, with the formation of a heated area in the region affected by the pressure trough. This pressure type continued with little change for several weeks during the summer of 1936, and abnormally high temperatures were recorded at some midwestern stations that lay in the region affected by the pressure trough.

The general movement of air in an east-west direction causes the interior valleys of the United States to become covered by an accumulation of warm air, which acts as a blanket in preventing the escape of heat. Convection currents rise with difficulty, owing to the increased pressure resulting from the excess air that has been carried into the interior. When clouds do form and spread out at higher levels, the temperature of the air at the cloud level is too high to permit rapid condensation. Consequently, little precipitation occurs, and the little

that does fall often evaporates before it reaches the ground. The air may contain a considerable percentage of moisture, yet drought continues and crops suffer because condensation does not occur. Condensation cannot occur under such conditions until the heat becomes so intense that convection currents finally break through the heated layer of air near the earth's surface and escape upward into a region of lower temperature which lies at greater altitudes. This results in violent thunderstorms with destructive winds and heavy precipitation over limited areas, while only a mile or so away there may be not even a trace of precipitation. This type of thunderstorm is characteristic of an arid climate.

If this abnormal condition is really due to the east-west elongation of the oceanic pressure areas, as the writer suggests, no decided change in the abnormal weather can occur until there is some change in the pressure areas. No great change in the pressure areas can occur while the general circulation continues to move at the same uniform velocity. But if the circulation should begin to move at a lesser velocity decided changes in the weather may confidently be expected.

These changes seem to occur approximately in the following manner. A decrease in the velocity of the general circulation causes, first, a decrease in pressure in the interior, due to the fact that the elongated pressure areas do not extend so far inland; second, a change in the position of the pressure trough with its attendant movement toward the south and east, due to the fact that the major axes of the pressure areas are shifting in an anticlockwise direction; third, a flow of moist

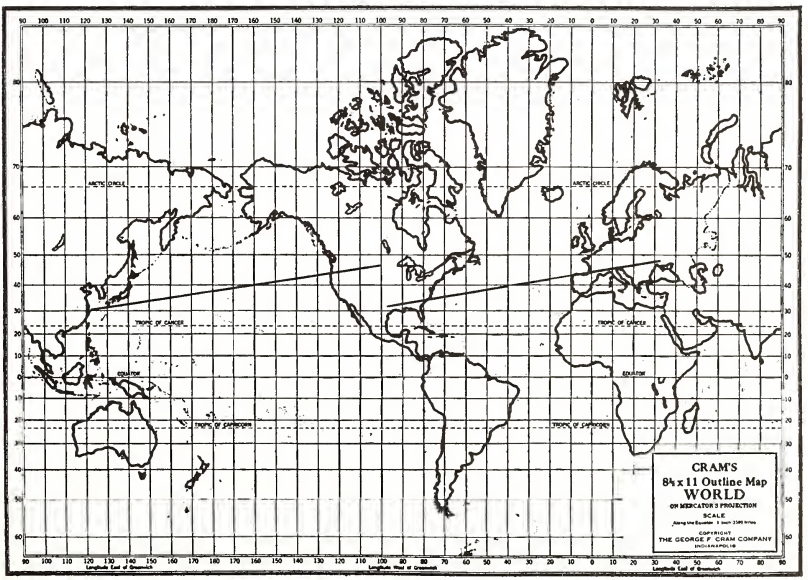

Fig. 3. The black lines show the approximate positions of the long axes of the oceanic pressure areas during periods of very rapid circulation. Note that the pressure ridge prevents all inflow of moist air from the Gulf.

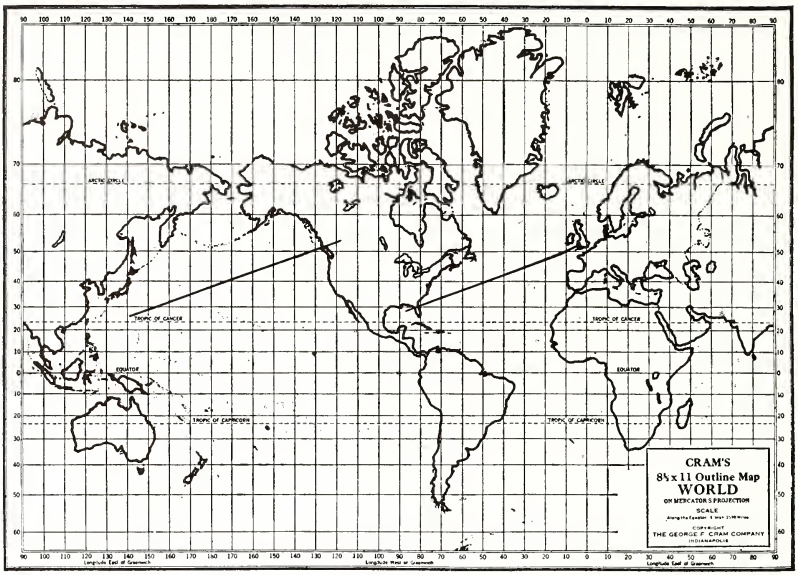

Fig. 4. The lines show the positions of the major axes when the circulation is less rapid. Note that the axes are shifting with an anticlockwise movement.

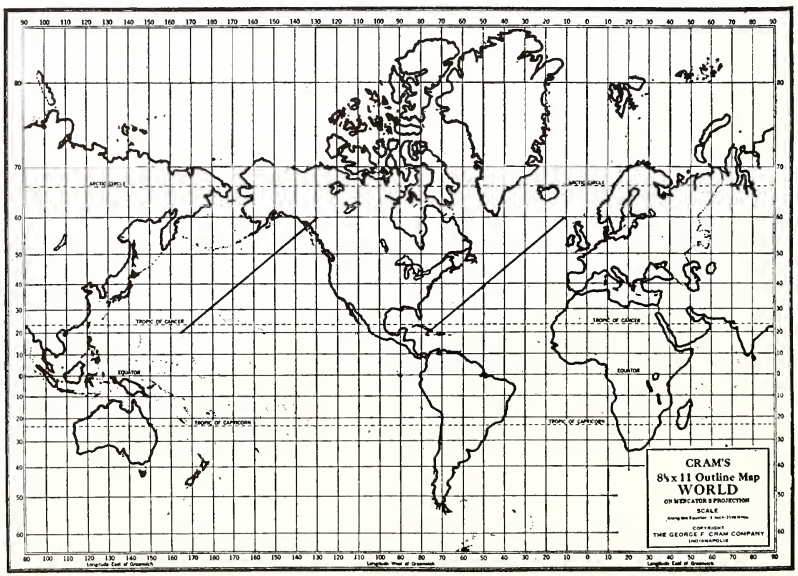

Fig. 5. A more sluggish condition of the atmosphere. The position of the major axes allows moist air to flow in from the Gulf, while cool air masses move down from the northwest.

air from the Gulf of Mexico into the interior, resulting from the breaking up and removal of the pressure ridge that extended across the southern states; and, fourth, a movement of cooler air from the northwest, due to the fact that the eastern end of the Pacific anticyclone has shifted into the higher latitudes.

These changes are illustrated in Figures 3, 4, and 5. The lines in each illustration represent the position of the major axes of the oceanic anticyclones. It should be remembered that a change to a more sluggish circulation causes, or permits, the major axes of the anticyclonic areas to shift or rotate in an anticlockwise direction, while a change toward a more rapid movement causes them to shift in a clockwise direction. Figure 3 shows the approximate position of the major axes during periods of rapid circulation during the summer season. Note the position of the pressure trough between the inland extensions of the two pressure areas. Clockwise winds blow around these major axes, and, as the winds move generally in an east-west direction, severe drought and abnormal heat prevails over widely extended areas. Figure 4 shows the shifting of the major axes which permit the pressure trough with its attendant heat wave to move eastward as the western extremity of the Atlantic anticyclone shifts eastward and southward over the Gulf. Figure 5 shows the further shifting of the major axes. This movement opens the way for an inflow of moist air from the Gulf, while clockwise winds moving around the Pacific anticyclone carry cool air southward to meet the warm moist air that is moving northward from the Gulf. When these air masses meet, the cool air acts as a condenser, showers develop along the cool front, and the earth is refreshed by much-needed rain. The showers may be expected to continue at frequent intervals as long as the circulation continues to move at the same decreased velocity.

Particular attention should be given to the fact that east-west movements are the predominating movements during periods of rapid circulation, but these movements weaken, and north-south movements become predominant as the circulation becomes more sluggish. Any assertion that westerly winds must always prevail in temperate latitudes may be somewhat misleading. Such an assertion is true only when the circulation is rapid. At other times the longitudinal movement eastward tends to develop into a latitudinal movement from some northerly or from some southerly direction. These latitudinal movements in a general north-south direction are responsible for the intermingling and the intermixing of air masses of different temperatures which results in a general instability of atmospheric conditions with an overturning of air masses and increasing precipitation.

If the same rapid circulation continues throughout the winter months, all continental and oceanic anticyclonic areas tend to unite in the form of a belt of increased pressure that extends across both land and sea. This seems to be due to the fact that all pressure formations must become elongated in the direction of their most rapid motion. Cyclonic storms move rapidly eastward along the northern side of this belt of increased pressure. Reed, in describing this type of weather on the Pacific coast, says:

Self evidently, with the general trend of air currents from west to east as prescribed by the lay of the isobars, cyclones would be required to travel eastward. Their speed of travel, too, consistent with this type of atmospheric circulation, needs no labored explanation . . . Northern districts may get almost continuous unsettled, rainy weather, with only a brief intermission between one storm and the next, whereas in southern districts the rainy regimes are relatively short and separated by well-marked periods of bright weather concurrent with shifts in the wind from southerly to northerly quarters and conspicuous fluctuations of temperature in conformity therewith. In other words, while northern districts are almost continuously in the belt of low pressure and its eastward-moving depressions, southern districts are almost continuously in the belt of high pressure which suffers inflections of varying degree as the traveling depressions pass along it on the northern side.[6]

Reed's description may be applied equally well to the weather in the interior, except that the unsettled, rainy weather does not pass over the mountains. The weather in the interior is usually mild with generally fair to partly cloudy conditions accompanied by subnormal precipitation and winds blowing generally from the south or southwest. The observed wind movement is due to the fact that the belt of high pressure extends across the United States while the pressure north of the international boundary is almost continuously low. Severe temperatures from above the Arctic Circle are carried southward by the anticlockwise circulation about the lows that move rapidly eastward across Canada, but these severe temperatures affect only the extreme northeastern parts of the United States. The lows move so rapidly, and changes in the temperature follow so swiftly, that residents of the New England states feel that a cold wave occurs "almost every night." Moderate to mild winter temperatures prevail over widely extended areas in the United States and western Canada at the same time. These mild conditions are characteristic of periods of rapid circulation.

These observations reveal another fact of primary importance which may be stated as follows: Unseasonably mild winter temperatures prevail over widely extended areas in the United States and Canada during periods of rapid circulation. These mild periods apparently are caused by the rapid circulation.

When the rapid eastward drift of the atmosphere in temperate latitudes becomes more sluggish, great changes occur in the direction of air movements. The broad belt of high pressure, which had extended from west to east across both land and sea, begins to break up into centers of action. The major axes of the anticyclonic centers shift in an anticlockwise direction. The former rapid movement from west to east becomes more sluggish, while the currents move more nearly in a southwest to northeast direction. This direction of air-flow can be easily recognized and traced on the weather charts published by the United States Weather Bureau. The San Francisco station prepares charts showing atmospheric conditions for some distance out over the Pacific Ocean. The data on oceanic conditions are gathered by ships at sea and reported to the mainland by radio. These charts show that the main air-flow during periods of rather sluggish circulation is from southwest to northeast over the ocean and from northwest

[6] Reed, Thomas R., 1932. Weather types of the northeast Pacific ocean as related to the weather of the north Pacific coast. Mo. Wea. Rev. 60:246-252.

to southeast after the air-flow has crossed the mountains. In other words, the main air-flow follows a path that may be likened to a very wide, inverted V with its apex pointing toward Alaska and the two sides being somewhat crescent-shaped. This type of air-flow permits the cold air masses from Alaska and northern Canada to move southeastward along the middle route, which leads across the lake region and into the Ohio Valley, and thence eastward toward the coast. It brings abnormally low temperatures to all of the region affected.

A further decrease in the velocity of the general circulation seems to cause a further development of the north-south movements. The air currents over the northeast Pacific Ocean flow more nearly in a south to north direction while the flow immediately east of the mountains is more nearly from north to south. The cold air masses then follow the western track southward toward Mexico and the Gulf Coast.

These observations suggest another fact of major importance. The lowest temperatures are carried farthest into the lower latitudes during periods of sluggish circulation. The low temperatures apparently occur in the lower latitudes as a result of the sluggish circulation.

According to good meteorological theory, low temperatures over widely extended areas in middle and lower latitudes should tend to increase the poleward temperature gradient and thus tend to speed up the circulation. According to careful observations which have been checked and rechecked many times, the lowest temperatures in middle and lower latitudes occur during the periods of most sluggish circulation. If these low temperatures have any effect in speeding up the circulation, that effect is so small that it has not yet been observed Again, according to accepted theory, mild temperatures in middle and higher latitudes should tend to decrease the poleward temperature gradient and thus cause the general circulation to become more sluggish. According to observation, the mild temperatures in middle and higher latitudes occur when the circulation is most rapid. If the mild temperatures have any effect in causing the circulation to become more sluggish, that effect is so small that it has not yet been observed. In other words, the observed movements are in direct opposition to good meteorological theory.

The accepted theory holds that the change in temperature comes first, and the change in circulation follows as a result of the change in temperature. The observations seem to indicate that the change in circulation comes first, and the change in temperature follows as a result of the change in circulation. In other words, the temperature changes apparently have no effect upon the circulation, but changes in the circulation have a very great effect upon the temperatures. This suggests that the difference in temperature between the equator and the poles may not be the primary factor in producing the general circulation of the atmosphere, as so many now believe. The general circulation may not be a convectional circulation. Can this possibly be true?

Reed has suggested that "weather types are essentially air-flow types, and the persistence of a weather type is consequent upon the persistence of an air-flow type."[7] If the observations made by the writer

[7] Reed, Thomas R., 1933. Some aspects of the free air winds in the far west. Mo. Wea. Rev. 61:42-43.

have been interpreted correctly, the persistence of any given type of air-flow is determined by the velocity of the general circulation. It seems, then, that a given type of weather will persist as long as the general circulation continues to move at the same uniform velocity. If these conclusions are correct, will it not be possible to forecast future weather trends for several weeks or months in advance when accurate data on the velocity of the general circulation have been obtained? This may not be as difficult as it seems. The normal movement is toward a more rapid circulation in winter and a more sluggish circulation during the summer. If the circulation becomes more active as summer approaches, can the weather observer be safe in predicting drought? If the trend toward sluggishness is greater than normal, will he not be able to predict timely rains and an abundant harvest? If a more complete knowledge of certain atmospheric variations will enable scientific men to foresee impending abnormalities in the weather, should they not give the matter the most careful study and earnest consideration?

This study of certain atmospheric variations has led the writer to the following definite conclusions.

1. All major weather changes in the United States, and possibly in all other parts of the world, seem to be due to changes in the form and position of the world pressure areas. These changes in the form and position of the world pressure areas apparently are due to variations in the velocity of the general circulation.

2. The longitudinal movement of the air, eastward in temperate latitudes, may not be a permanent feature of a planetary wind system. It may be replaced by a latitudinal movement from some northerly or from some southerly direction.

3. Temperature apparently does not affect the circulation in just the way that is generally believed, but the circulation has decided effects upon the temperature.

4. A more complete knowledge of the variations in the velocity of the general circulation may be of decided advantage in forecasting future weather trends.

PROGRAM OF THE SECTION ON MATHEMATICS

Chairman: C. K. ROBBINS, Purdue University

1. On the foundations of geometry. Karl Menger, University of Notre Dame.

J. E. Dotterer, Manchester College, was elected chairman of the section for 1938.

A Foundation of Projective Geometry

KARL MENGER, University of Notre Dame

We assume a system of elements denoted by A, B, . . . and two operations which associate with any two elements A and B, an element $A+B$ and an element $A.B$. The operations may satisfy the following conditions:

I. Associativeness: $A+(B+C)=(A+B)+C$, $A.(B.C)=(A.B).C$.

II. Existence of two indifferent elements V ("vacuous" element) and U ("universal" element) such that for each element A we have:

$$A+V=A, \qquad A.U=A,$$
$$A.V=V, \qquad A+U=U.$$

III. A weakened distributive law:

$$A+(A+B).C=A+(A+C).B, \qquad A.(A.B+C)=A.(A.C+B)$$

From these assumptions we easily deduce that both operations are commutative and, for each A and B, satisfy the condition $A+(A.B)=A=A.(A+B)$. Consequently, if we have $A+B=A$ for two elements A and B, then we also have $A.B.=B$, and conversely. If for two elements A and$B$ both formulas $A+B=A$ and $A.B=B$ hold, then we call B a part of A. The part relation defined in this way has the ordinary properties. From C part of B, and B part of A, it follows that C part of A, etc.

We furthermore easily derive the formula $A+A=A=A.A$ for each A, by virtue of which there are neither multiples nor powers in the formulas of the algebra of geometry derived from the postulates I, II, III. We get thus: A part of A for each A; besides: V part of A, and A part of U on account of postulate II. Those elements which are different from V and do not contain any other parts than themselves and V shall be called points. Those elements which are different from U and are not part of any other element than themselves and U shall be called hyperplanes. Our definition makes precise the famous first words of Euclid's Elements: "Point is that which has no parts."

n points are called independent if for each of them the product of the point and the sum of the n-1 other points is V. In an analogous way, n hyperplanes are called independent if for each of them the sum of the hyperplane and the product of n-1 other hyperplanes is U. These definitions yield a theory of linear independence including in particular the following theorems: If an element is the sum of a finite number of points, then it may also be represented as the sum of independent points. If two systems of independent points have the same element A as sum, then the number of points in both systems is necessarily the same. We shall denote this number by a'. If an element is the product of a finite number of hyperplanes, then it may also be represented as the product of independent hyperplanes. If two systems of independent hyperplanes have the same element A as product, then the number of hyperplanes in both systems is necessarily the same. We shall denote this number a''.

If both A and B are elements which may be represented as the sum of a finite number of points, then the same holds for the elements $A+B=S$ and $A.B=P$, and we can prove that the number $a'+b'$ is not less than $s'+p'$. If both A and B may be represented as the product of a finite number of hyperplanes, then the same holds for S and P, and we can prove the number $a''+b''$ is not less than $s''+p''$.

In order to complete the theory, we need now two further postulates:

IV. If the point P is part of A, then there exists an element A' such that $P+A'=A$ and $P.A'=V$. If the element A is part of the hyperplane H, then there exists an element A'' such that $H.A''=A$ and $H+A''=U$.

V. A monotonic sequence cannot contain infinitely many different elements, i.e. if in the sequence $A_1, A_2, A_3, \ldots$, each element is part of the following element, or each element is part of the preceding element, then all elements of the sequence from a certain element on are identical.

These two postulates guarantee that each element A may actually be represented as the sum of a finite number of points, and as the product of a finite number of hyperplanes. Furthermore, Dr. F. Alt (Vienna) deduced from them that the number $a'+a''$ is the same for each element A, namely, equal to the number of independent points whose sum is U, and to the number of independent hyperplanes whose product is V. This formula together with the previously mentioned inequalities yields the formula $a'+b'=s'+p'$ for any two elements A and B.

We define now the dimension of an element A as the number of independent points whose sum is A, diminished by 1, thus dim $A=a'-1$, and set dim $V=-1$. For each element A the number dim A surpasses by exactly 1 the largest dimension of any part of A which is different from A. We have, furthermore, the formula:

dim A+dim B=dim $(A+B)$+dim $(A.B)$ for any two elements A and B.

Points are the elements of dimension O. If we call "straight line" each element of dimension 1, and say that a point P and a line L coincide if P is part of L, and if we add the postulate

VI. dim $U=n$,

then it is easy to deduce the ordinary postulates of projective geometry of the n-dimensional space, except the postulate that each straight line contains at least three distinct points. This postulate is easily seen to be equivalent to the following one:

VII. For any two distinct points P and Q there is an element A such that the distributive formula $A.(P+Q)=(A.P)+(A.Q)$ does not hold.

If we postulate, on the contrary, the distributive law

VII.* $A.(B+C)=(A.B)+(A.C)$ and $A.(B+C)=(A+B).(A+C)$ for any three elements A, B, C

(in which case the postulates I-V may be considerably simplified), then we get a Boolean algebra of classes. Under the assumption VI, the system of elements is isomorphic with the system of the 2^{n+1} subsets of a set containing exactly $n+1$ elements.

PROGRAM OF THE SECTION ON PHYSICS

Chairman: LESLIE I. STEINBACH, Central Normal College

1. Quadruple rotation—vibration spectrum of hydrogen. Hubert M. James, Purdue University.
2. Minimum stopping distances for automobiles. R. E. Martin, Hanover College.
3. The crystal detector as a rectifier of short waves. Mildred Williams Bulliet, Rockford, Illinois.
4. The angular distribution for resonance disintegration. R. D. Myers, Purdue University.
5. The basic principles of the physics of the universe. Arthur Haas, University of Notre Dame.
6. Comparison of the structure of natural and synthetic rubber. Eugene Guth, University of Notre Dame.
7. Collision of two Dirac particles. J. Franklin Carlson, Purdue University.
8. The structure of the non-crystalline forms of selenium. E. P. Miller and K. Lark-Horovitz, Purdue University.
9. Anomalous dispersion of calcite in the x-ray region. Robert M. Whitmer, Purdue University.
10. Can ferro-magnetism be detected by x-rays? K. Lark-Horovitz, Purdue University.
11. Effect of fringing flux in large magnets. J. D. Howe and I. Walerstein, Purdue University.
12. The production of radioactive substances by bombardment with alpha particles. W. J. Henderson, Purdue University.
13. Asymmetric radiation produced by cathode rays. Victor G. Reiling and George B. Collins, University of Notre Dame.
14. Likenesses and differences of resonance curves produced by damped wave and continuous wave transmitters. R. R. Ramsey, Indiana University.
15. Modulation. Herbert C. Hazel, Indiana University.
16. Stochastic processes and generating functions. E. S. Akeley, Purdue University.
17. The earth's forces and motions. A. F. Foley, Indiana University.

Seth Elliott, Butler University, was elected chairman of the Section for 1938.

ABSTRACTS

Quadrupole rotation-vibration spectrum of hydrogen. HUBERT M. JAMES, Purdue University.—Herzberg has suggested that it may be possible to prove the existence of hydrogen in planetary atmospheres

by observation in absorption of its quadrupole rotation-vibration spectrum. To make possible a quantitative discussion of this problem the theory of quadrupole transitions between Σ states of homonuclear diatomic molecules has been worked out and applied to this system. The quadrupole moment has been computed as a function of nuclear separation by the use of electronic wave functions obtained by a variational process. Matrix elements of this quantity have been computed using Morse and Pöschl-Teller vibrational functions. It is found that the intensity of the first line of the S branch of the fundamental band of hydrogen is $7.7\times10\text{-}9$ of that of the first line of the R branch in the fundamental band of hydrochloric acid. The first and second overtone bands have respectively .86 and .18 of the intensity of the fundamental band. It appears that this relative intensity, very much greater than that observed with dipole bands, is of the order to be expected in quadruple overtone bands in general.

The angular distribution for resonance disintegration. R. D. MYERS, Purdue University.—Using the Bohr scheme for the disintegration process, i.e., the formation and decomposition of a compound nucleus, the angular distribution is calculated when only one state of the compound nucleus is important. It is found that, in the co-ordinate system moving with the center of gravity, the produced particles are axial symmetric about the incident beam and are symmetric with respect to the plane normal to this axis. Further the highest harmonic found in the distribution cannot be greater than twice the l of the incident wave or the J of the compound state. (This rule was guessed but not proved by Teller.) The results are applied to the several experimental results of Neuert for the disintegrations:

$$Li^7 + H^1 \rightarrow Be^8 \rightarrow He^4 + He^4$$
$$D^2 + D^2 \rightarrow He^4 \rightarrow H^3 + H^1$$
$$Li^6 + D^2 \rightarrow Be^8 \rightarrow Li^7 + H^1$$
$$B^{11} + H^1 \rightarrow C^{12} \rightarrow Be^8 + He^4$$

The basic principles of the physics of the universe. ARTHUR HAAS, University of Notre Dame.—Physics of the universe may be based upon the following assumptions: (1) The radius of the universe is at the same time its gravitational radius (or $fM/c^2 = R$, where f is Newton's gravitational constant, M the mass of the universe, R its radius, and c the velocity of light); (2) For the largest distance possible in a closed universe (that is for πR) Hubble's recessional velocity becomes equal to the velocity of light; (3) The ratio A of the electrostatic force between a proton and an electron to the gravitational force between them is identical with the ratio of R to a, the classical radius of the electron ($a = e^2/(mc^2)$).

The use of these three principles leads to the relation that the total number of protons and neutrons in the universe is equal to A^2, that is equal to $(R/a)^2$. For the relation between the gravitational constant and Hubble's factor u ($u \approx 500$ km./sec. per mega-parsec.), there follows the equation:

$$f = (\pi\, e^2\, u\, a) \,/\, (m_p\, m\, c)$$

where m_p is the mass of the proton. On inserting the well-known values into the right-hand side of this formula we obtain for f, in perfect agreement with observational data, a value of 7×10^{-8}.

Comparison of the structure of natural and synthetic rubber. EUGENE GUTH, University of Notre Dame.—Rubber is built up from chain molecules, so-called macromolecules. All such substances, whether occuring naturally or prepared artifically, are invariably mixtures of molecules of different dimensions. This holds as long as they have not been fractionated into more or less homogeneous fractions. Under these circumstances, only a mean molecular weight of such macromolecular substances has a real meaning.

For long chain molecules the molecular weight is equivalent to a certain length of the chain of a certain number of chain links. The mean molecular weight is therefore equivalent to a certain mean length of the chain. It is now important that the different methods for the determination of this mean chain length generally lead to different results. In other words, the averaging process which gives us a mean chain length is not completely determined but depends on the kind of measurement used.

It is well-known both in pure science and in industry that one can get at least an estimation of this mean chain length by means of viscosimetric measurements. The greater the viscosity, the larger is the chain length. Analogous remarks hold concerning the determination of another mean chain length from osmometric measurements.

On the other hand, the tensile strength of a long chain compound also gives an estimate of a mean chain length. The larger the tensile strength, the larger is the chain length. But the chain length is not the only factor which determines the tensile strength. This depends also on the distribution function for the chain lengths. Of two substances with equal maximal chain lengths, that with a steeper distribution function will have the greater tensile strength. Steeper distribution function means greater chemical regularity of the structure.

Comparative measurements of the viscosity of crepe rubber and synthetic rubber on the one hand, and of the tensile strength of these substances on the other hand, lead to a surprising result. While the viscosity of a solution of rubber in benzine was two times as great as an equally concentrated solution of crepe rubber in the same solvent, the tensile strengths of both substances were approximately the same.

The explanation is that synthetic rubber has many longer chains than crepe rubber, but the influence of these chains on the tensile strength is over-balanced by the presence of a still greater number of much shorter chains, which the crepe rubber has on the average. This fact is also important for the elasticity of synthetic rubbers.

Collision of two Dirac particles. J. FRANKLIN CARLSON, Purdue University.—The collision cross section for two particles of arbitrary mass, charge and relative velocity is calculated on the assumption that the behavior of both particles may be described by Dirac wave functions. The effects of the retardation of the forces and the magnetic interactions are taken into account following a method due to Moller.

The expression for the differential cross-section obtained contains three types of terms. The first type is of the ordinary classical form. The other two types give the deviations due to retardation and the magnetic forces. In the interesting case of the collision of a high energy proton with an electron at rest these added terms become important only if the incident proton has an energy of the order of 10^{12} electron volts and if the energy transferred is comparable with the incident energy of the proton.

The structure of the non-crystalline forms of selenium. E. P. MILLER and K. LARK-HOROVITZ, Purdue University.—Using monochromatic x-rays the x-ray diffraction patterns of amorphous, liquid, and glasseous selenium have been studied. They are found to be identical within the limits of experimental error. The patterns have been analyzed by Fourier analysis, and it has been shown that each atom has only two nearest neighbors: thus only chains and rings can constitute the elementary domains in these forms. Experiments on the elastic properties of amorphous selenium by K. H. Meyer lead to the conclusion that chains must be the constituents. The results are discussed in connection with recent investigations on the question: is glass a super cooled liquid or a crystal?

Anomalous Dispersion of calcite in the x-ray region. ROBERT M. WHITMER, Purdue University.—The index of refraction of calcite for x-rays in the vicinity of Ca k-absorption edge has been determined, using a crystal having a face ground and polished so that a part of the emergent beam has a very small emergence angle and so is refracted appreciably. A new feature consists of splitting a single emergent beam striking one face of crystal into two emergent components. The theoretical works of Kallmann and Mark, Suguira, and Honl are reviewed and the results of the experiment compared with those of Honl.

Can ferro-magnetism be detected by x-rays? K. LARK-HOROVITZ, Purdue University.—Recalling that all magnetic properties of materials can only be understood as quantum phenomena and that ferro-magnetism in particular has to be considered as a spin exchange phenomenon in solids, the different possibilities for x-ray applications are discussed. It follows at once that no change in structure is to be expected and none has been observed. Considering intensities, the transition probabilities and oscillator strength for atomic levels and crystal levels have to be discussed. It can be shown that no effect can be observed in the *K*-region of x-rays, and the possibility to observe effects in the *L*-region is excluded by intensity considerations.

Effect of fringing flux in large magnets. J. D. HOWE and I. WALERSTEIN, Purdue University.—In the design of the magnet for the Purdue cyclotron the pole pieces were shaped in such a way as to obtain as high a value for the velocity of the accelerated particles as possible. This design, in common with all other types of design, results in a considerable amount of magnetic flux fringing in the space outside the pole gap. The Ampere interaction of this fringing flux with the current in the energizing coils produces a force which may even be larger than

the weight of the coils. Furthermore this force is one causing a repulsion of the coils away from the neighborhood of the gap, and if the axis of the coils is vertical, the upper coil has a tendency to "float." Complete mapping of the magnetic field in the neighborhood of the pole pieces showed that for an energizing current of 160 amps the field in the air gap between the pole pieces is 15,200 gauss, and the horizontal component of the field in the neighborhood of the coils has an average value of 750 gauss. The resulting force on the upper coil amounts to a lift of 3.4 tons.

The production of radioactive substances by bombardment with alpha particles. W. J. HENDERSON, Purdue University.—The elements B, N, Mg., Al, P, Cl, Cr, NiCo, Cu, As, and Br have been bombarded with 9 M. E. V. alpha-particles accelerated in a cyclotron. The half lives and thick target yields of the resulting radioactive bodies have been measused. In a few cases the energy of the β -rays emitted has been estimated by the absorption method. Where the radioactive isotopes were not previously known, they have been identified by chemical tests, on the sign of the charge on the electrons emitted, and by correlation with results with other bombarding particles. The experiments were done at Princeton University in collaboration with L. N. Ridenour.

Asymmetric radiation produced by cathode rays. VICTOR G. REILING and GEORGE B. COLLINS, University of Notre Dame.—The asymmetric emission of light produced in a liquid by electrons of high velocity, which was first reported by Cerenkov, has been verified. 1400 k.v. electrons (3 μa.) were used to produce the light emission. The effect was also found to occur in solids such as glass and mica. Water, methyl alcohol, benzene, and carbon tetrachloride all were found to produce the asymmetric radiation. It was also verified that the direction of emission with respects to the direction of the cathode rays depends upon the refractive index of the medium in which the light is produced.

Modulation. HERBERT C. HAZEL, Indiana University.—In order that one periodic disturbance may modulate another, a product of the two must be produced in some way. Sounds from separate loud speakers actuated by audio oscillators give no product terms in air. Analysis by an acoustical wave-meter showed no combinational tones present, though the beat notes were uncomfortably loud in the ear. Connecting two speakers together with wire likewise failed to produce modulation. However, impressing one frequency upon the field coil and another upon the voice coil of a dynamic speaker gave distinct modulation products. There has been, and still is, great confusion among physicists concerning the conditions for modulation and the objective reality of frequencies produced by modulation. Frequencies derived from modulation, which must involve a multiplication of parent disturbances, elicit peak response in devices tuned to them.

Stochastic processes and generating functions. E. S. AKELEY, Purdue University.—We shall consider the motion of a system of n particles where the probability that the system is in a given state is a function of its state at a previous instant of time. Generating functions are

given for computing the probability of transition from one state to another in terms of the transition probabilities for the particles themselves, both in the case of the classical and the Bose-Einstein statistics. Methods are given for computing mean values of functions of the state of the system.

The earth's forces and motions. A. L. FOLEY, Indiana University.—The author will show that some of the statements of text books about gravity, the center of the earth, and the earth's motions are not strictly true. Some are very far from being true.

Minimum Stopping Distance of Automobiles

R. E. Martin, Hanover College

The ever-mounting toll of deaths on the highways due to excessive speeds of automobiles produces a problem of unusual significance. Many factors contribute to these high speeds—better roads, faster cars, use of alcohol, a growing desire for the thrill which results from fast driving, competition in all phases of living, and loose talking about high speeds attained. Certainly anything that can be done to reduce this toll should be done. It was thought that if drivers realized the least distance in which they could stop their cars in the event of necessity, then some of them might drive more carefully.

Of course, work on this phase of the problem is not new, nor is any claim made for originality in the solution of it. However, this problem is important enough that it should be kept before the driving public until something is done to reduce the death toll. Some worthy papers have been published on this problem. The most complete of these that has come to my knowledge is that of the Iowa State College of Agriculture and Mechanical Arts, Bulletin 120. This work at Iowa was conducted for a different purpose than that outlined above, and, of course, the results obtained were used differently. In that work the data were gathered to enable the highway engineer to provide sufficient view of approaching cars at a road intersection, and this information was made available to those engineers and not to the motoring public.

Due to the lack of funds, time, and personnel, the present work does not compare with that mentioned above. But it is thought that this work will bring the problem up to date and present it to a different audience for a different purpose. The fact that the Iowa College repeated its work in 1928 and 1932 after having first performed it in 1924 indicates that this is a problem that should be considered frequently.

The forces that bring a car to rest when in motion may be considered in two groups, (1) the force due to the brakes, (2) the forces due to the compression in the engine, the surrounding atmosphere, and rolling friction. In this work the combined effect of the forces in the second group has been determined. In most of the other papers these forces have been determined separately and their effects either neglected or combined. While various opinions and ideas may be had about the effect of the brakes and also their use, it seems that when an emergency arises the operator of the car will, in most cases, exert all the force he can on the braking system. This being the case, then we can determine the maximum effect, in case the brakes on the car are in good order, by measuring the coefficient of sliding friction and applying it to the problem.

In attacking this problem, then, I measured the coefficient of sliding friction for both new and used tires on the different types of roadway. This was done in the usual manner by dragging over the roadway a two-wheeled trailer equipped with the tires to be tested and measuring

the horizontal pull required, with the suitable dynamometers. This pull being known, the coefficient of sliding friction, k, was calculated as follows (Fig. 1): If P represents the horizontal pull, W the total weight

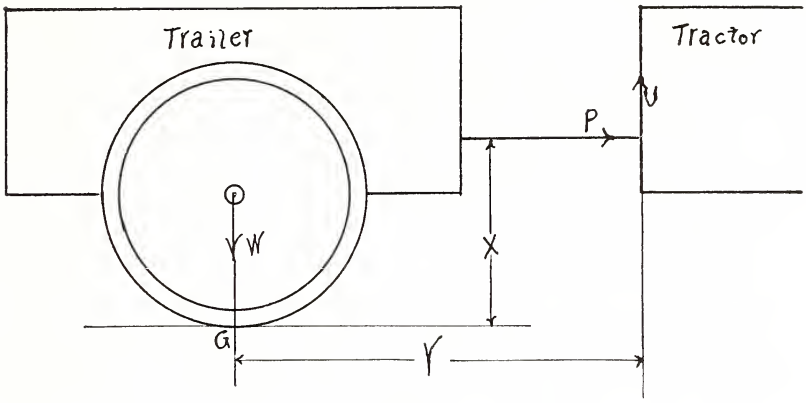

Fig. 1.

of the trailer, U the weight transferred to the tractor by the torque action due to fricion, Y the lever arm of the force U, and X the lever arm of the force P, then, $UP=PX$ (taking moments about G, the point of contact between tire surface and roadway). From the definition of the coefficient of friction, k is equal to W divided by, W minus U. After measuring P, W, X, and Y, k could be determined from the relation, $k = \frac{PY}{WY - XP}$. The values obtained are shown in Tables I-III.

TABLE I—Coefficients of Friction—Concrete Road

New Tires

Road Wet		Road Dry	
Speed mi./hr.	Coef.	Speed mi./hr.	Coef.
6.0	.55	5.4	.82
10.5	.51	11.0	.75
16.0	.45	15.25	.69
20.0	.41	21.0	.62
26.25	.38	25.5	.58

Old Tires

4.8	.65	5.0	.74
9.7	.61	10.3	.65
15.1	.50	14.8	.59
20.0	.43	21.0	.52
24.6	.37	25.6	.48

TABLE II—Coefficients of Friction—Asphalt Road

New Tires

Road Wet		Road Dry	
Speed mi./hr.	Coef.	Speed mi./hr.	Coef.
4.7	.75	5.2	.88
9.8	.66	10.9	.81
15.1	.56	15.6	.77
20.4	.48	21.0	.74
25.0	.43	25.6	.71

		Old Tires	
4.9	.62	5.0	.81
10.2	.54	10.4	.76
14.8	.46	14.9	.72
21.0	.34	21.0	.68
24.6	.30	25.6	.65

TABLE III—Coefficients of Friction—Limestone Road

Road Wet		Road Dry	
Speed mi./hr.	Coef.	Speed mi./hr.	Coef.
		New Tires	
4.8	.60	5.1	.61
10.2	.61	9.8	.63
14.9	.63	15.1	.65
20.6	.69	20.2	.70
24.8	.71	25.0	.73
		Old Tires	
5.0	.57	4.8	.58
10.2	.59	10.2	.60
15.1	.60	15.0	.64
19.8	.63	20.8	.67
24.6	.65	25.3	.69

It will be noted that these values are for speeds up to approximately 25 miles per hour. This shortcoming, common to all work on this problem, was due in this case to the limitations of the vehicle used to furnish the motive power, namely a tractor ordinarily used to pull a gang lawn mower. The extent of this shortcoming is significant, for at these speeds the stopping distance is not a problem but only becomes so at considerably higher values, say from 50 miles per hour and upward. In an attempt to reach values for the coefficient of friction which would be of service at these higher speeds, the data obtained in the tests were plotted, showing the variation of coefficient of friction with speed, and the curves thus obtained extended up to 50 miles per hour. In extending these curves it is realized that at best this is only an approximation, but in all cases an effort was made to make the error, if any, in the direction of a larger coefficient.

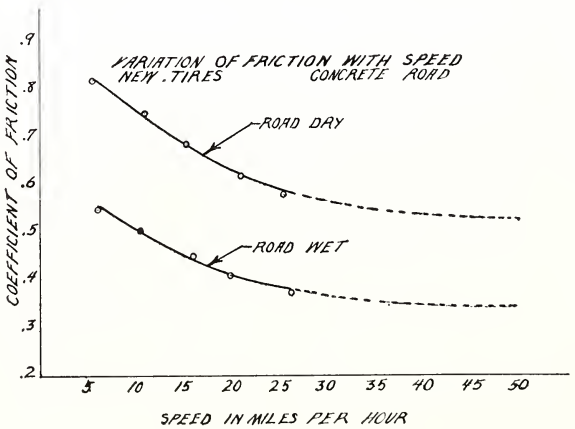

Fig. 2.

In the set of curves shown in Figure 2, which is for new tires on a new concrete road, it is quite evident that when the road is dry the coefficient cannot be more than .48 at 50 miles per hour, and when the road is wet not more than .34 at the same speed. Without any stretch of the imagination, much lower values might be assumed at this higher speed. The next three sets of curves (Figs. 3-5) are similar to the

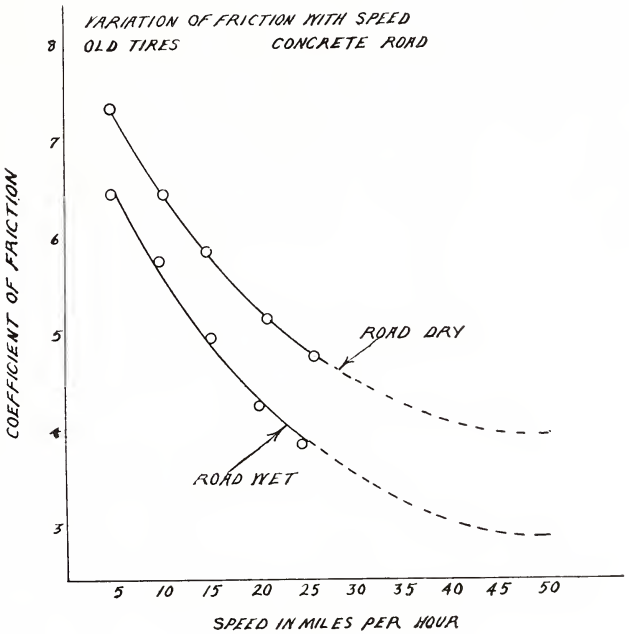

Fig. 3.

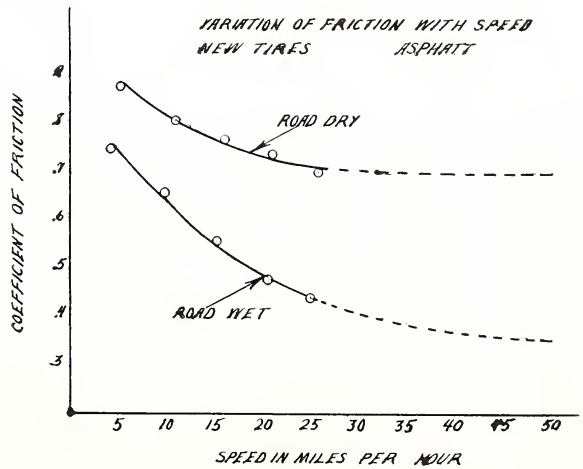

Fig. 4.

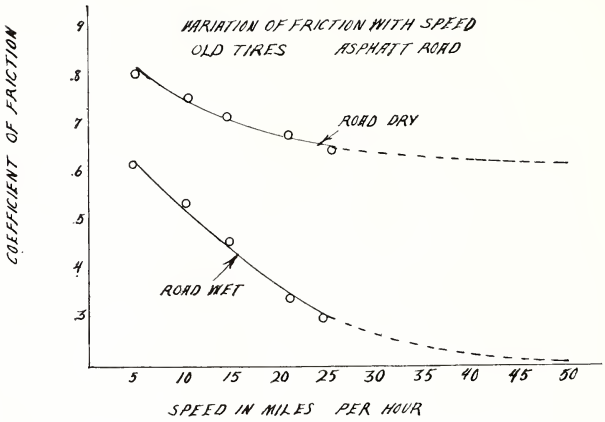

Fig. 5.

first and show conclusively that, for the types of road surfaces which they represent, the coefficient of sliding friction decreased with speed, reaching a value at high speeds much less than that for low speeds.

Now it is these high-speed values that determine the minimum stopping distances with which we are interested. Very few accidents are caused by being unable to stop quickly when traveling at 25 miles per hour. Hence, in my computations, the results of which will be given later, I used the coefficients determined for the speeds involved.

The two sets of curves, Figures 6 and 7, which are for both new and old tires on a well worn limestone road, are interesting in that they show that the coefficient of friction increases with speed. Some interesting results might be obtained by applying the same method of analysis to these curves, but, since high speed roads are not of this character, the results would not be very significant. This increase in coefficient for certain types of roadway has been noted by other experimenters, some of whom attribute it to the roughness of the surface, the effect of which increases with speed. In this work I am interested most in the

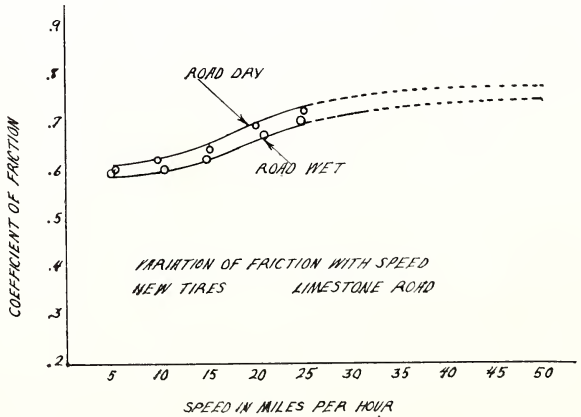

Fig. 6.

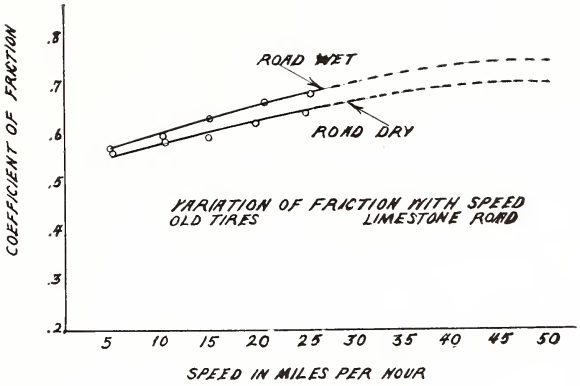

Fig. 7.

values taken from the first four sets of curves since they apply to the most common high-speed roads which we have in Indiana.

Also, the second group of forces mentioned above varies considerably with speed, a fact that I have not found considered by other workers on this problem. I determined this relationship for several cars. While the general trend for each was the same, the numerical values varied considerably, depending upon the model, age, mileage, and other particulars. The method was very simple. Selecting an approximately level strip of

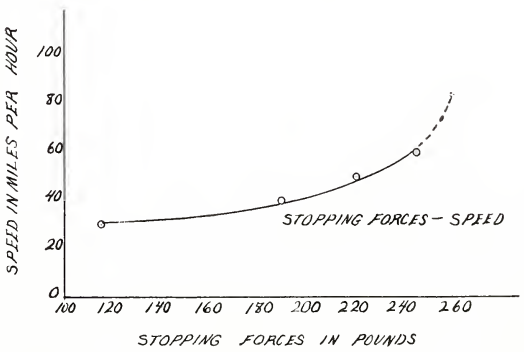

Fig. 8.

roadway, a day without a wind, and a car with an experienced driver, when the desired speed had been obtained, I turned off the ignition, and we let the car run with the clutch in until it stopped. We then measured the distance traveled while coming to rest. We took a similar set of observations while the car was traveling in the opposite direction over the same course so as to eliminate as far as possible the effects of grade and wind. Figure 8 shows a typical set of data. The car used was a

1937-model Chevrolet sedan, which had been driven about 2,000 miles. The mass of this car being known, the combined stopping forces were computed from the following relation: Force $= \frac{MV^2}{2D}$. M is the mass in slugs, V the velocity in feet per second at the beginning of the test, and D is the distance traveled while stopping. The force will then be expressed in pounds. It is evident from the figure that no constant value can be assigned to the resultant of this set of forces, but as speed changes, the value will change.

To combine our stopping forces, let us consider the car mentioned above, whose mass, when loaded with fuel, oil, water, and a 160-pound driver, is 3360 pounds, or, 105 slugs. Since the coefficient of friction varies with speed, and the distance traveled while being brought to rest varies with the square of the initial speed, it is necessary to find a so-called "effective speed" in order to determine the proper coefficient to use. This effective speed is defined as that single speed at which the car would have to travel to cover the same distance in the time which elapses while the car is being brought to rest. It can be shown to be equal to $\frac{V}{\sqrt{3}}$, where V is the speed at the instant the brakes are applied. The distance traveled while being brought to rest by the combined action of all the stopping forces is then given by the relation, $D^1 = \frac{MV^2}{2F^1}$, where F^1 is the force due to braking plus all other retarding forces, and the other terms represent the quantities heretofore assigned.

The stopping distance is also dependent on the "reaction" time of the driver. This reaction time has been determined by a number of experimenters recently. One such determination was made in the Indiana University Building at the State Fair of 1936. Due to the kindness of Dr. Frank Elliott, Director of Publicity, the general results of this determination have been made available to me. This "reaction" time has also been determined recently by the Keystone Automobile Association. It is generally believed that this time is slightly more than .5 seconds. But in all of these determinations the person being tested was expecting a signal. If this factor of expectancy is removed, psychologists are of the opinion that the reaction time is increased by at least 50%. While this is not the most important factor in this problem, yet it is of some weight and should be considered. It will account for a few extra feet, and in some automobile wrecks this may mean quite a lot.

The total stopping distance is then given by the relation, $D^{11} = \frac{MV^2}{2F^1} + Vt$, where all symbols have the significance defined above and t is the "reaction" time, which I have taken to be .75 seconds. Using this relation the values shown in Table IV were obtained.

TABLE IV—Minimum Stopping Distance

Initial Velocity	Concrete Road				Asphalt Road			
	Wet		Dry		Wet		Dry	
	New tires	Old tires	New tires	Old tires	New tires	Old tires	New tires	Old tires
10 mi./hr.	15 ft.	16 ft.	15 ft.	16 ft.	16 ft.	17 ft.	15 ft.	15 ft.
20	41	45	39	41	43	47	38	39
30	93	97	76	84	87	103	72	75
40	165	160	125	139	149	187	113	119
50	253	257	189	212	232	291	165	171
60	351	372	266	301	338	451	224	237
70	472	489	353	408	463	631	281	289
80	601	670	429	536	578	834	364	395
90	767	859	553	680	735	1007	452	494

From a graph published by Dr. Arthur L. Foley in his College Physics, we find that the minimum stopping distance for a car going 60 miles per hour under ideal conditions of roadway and tire surface is 222 feet. This value is somewhat less than most of mine, which are, 351, 373, 266, 301, 338, 451, 224, and 237, depending upon the type of road surface and the tires used. The Iowa Bulletin mentioned above gives a value of 250 feet for an initial speed of 61 miles per hour on an average surface.

This difference between the values which I have obtained and those of other experimenters is due primarily to the fact that I have used a coefficient of friction which varies with speed, and they have used a coefficient determined at a lower speed than that which would be experienced on the road while the car was being stopped. So far as I have been able to find out, all other experimenters have obtained this variation with speed but have not used it in their computations.

In conclusion, then, may I add that the experimental work which I have done only brings this problem up to date, but the use of the values obtained is new and leads to results quite different from those previously determined. Since life and property are at stake in the application of these results, perhaps this work will justify itself if it calls attention to these larger distances to be expected.

I am deeply indebted to the Research Committee of the Indiana Academy of Science for providing the funds necessary to carry out this experimental work. To Dr. Arthur L. Foley, chairman of that Committee, I am especially indebted for his interest and appreciation of the importance of the work. Mention should also be made of Mr. David Edwin Hine and Louise Martin, two of my students, who assisted me in the work.

The Crystal Detector as a Rectifier of Short Waves[1]

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The present paper is a report of an investigation into the supposed identity of Hertzian and heat waves.

Hertzian[2] and heat[3] waves that are polarized are reflected or transmitted by wire gratings in the same manner. Both groups of wave lengths have the property of being reflected when the grating has its elements parallel to the plane of polarization and transmitted when they are at right angles. In Hertzian waves this plane is identified with the direction of the spark. In the case of reflection, apparently a current is produced in the grating to give an opposing effect when parallel. An attempt was made to find this current in both wave length groups.

As a crystal detector seemed to be the only means available for detecting short waves, preliminary data were taken to determine if it were capable of detecting very short waves. An interference apparatus, as in Figure 1, consisted of two plain metallic mirrors, M_3 stationary,

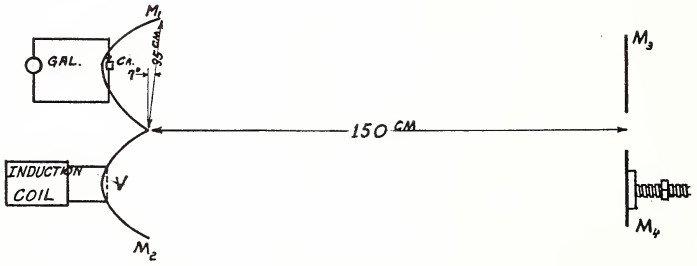

Fig. 1.

and M_4 set on a wooden base which was moved by a screw, and two parabolic metal mirrors, M_1 *and* M_2, with spark transmitter and galena crystal detector placed at their respective foci. Two spark gaps were made for producing waves of different lengths. For eight-centimeter waves, two ⅝ penny brads supported brass balls eight millimeters in diameter. The spark between the balls occurred in oil, and the connection to the induction coil was by air gaps. For four-millimeter waves, bits of No. 40 copper wire were cut in one-millimeter lengths, immersed in oil, and connected to the induction coil through Geissler tubes. To obtain the data for all of the positions of M_4, corresponding readings were taken on the galvanometer. The data are indicated in graphs 2 and 3.

[1] Submitted in partial fulfillment of the requirement for the degree, Doctor of Philosophy, in the department of physics in the Graduate School of Indiana University.

[2] Hertz, Electric Waves, 178.

[3] DuBois, H., and Rubens, Annalen der Physik, 32:243.

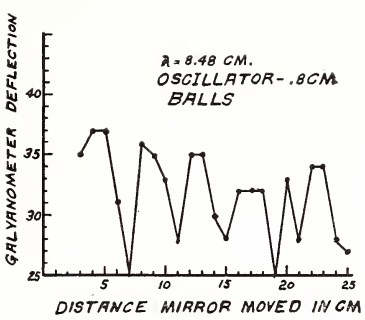

Fig. 2.

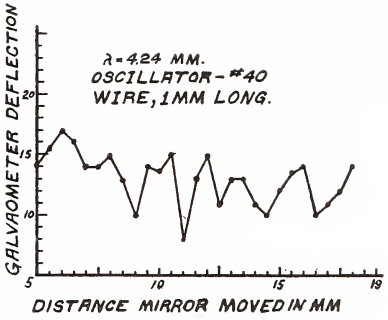

Fig. 3.

The wave length produced by the vibrators, as determined with the crystal, checked with data taken by other experimenters. The crystal was found to be sensitive to waves as short as four millimeters. Shorter waves of uniform length were not obtained.

In an effort to establish the fact that a current was produced in the grating by polarized spark waves, a grid was connected to a crystal detector and a sensitive galvanometer. The grids ranged in shapes from twelve inch squares to rectangles 5 by 30 inches. They also varied in size and in the number of wires. The spheres or oblong oscillators used to produce the spark waves transmitted wave lengths from eight centimeters to several meters. In some of the oscillators the spark occurred in oil. All were connected to the induction coil through air gaps. The induction coil was not shielded for some of the data. However, practically all data were taken with the induction coil either in a grounded copper screen box or in a steel box. In all of the data taken, no difference was indicated as to whether the grid was parallel or perpendicular to the plane of polarization. This electromotive force introduced into the untuned grid indicated the same spurious effect that Smith-Rose[4] called the "antenna effect" in the untuned practical direction finder.

In a receiver tuned to a short radio wave transmitter, a maximum electromotive force was indicated on the galvanometer when the receiver was parallel to the transmitter and none when it was horizontal. An untuned receiver under the same conditions gave the same small reading in both cases.

Since an electromotive force was found to exist in a wire grid that is excited by spark waves, an effort was made to find in a fine grid the existence of an electromotive force that was produced by heat waves.

This fine grating made by the National Bureau of Standards consisted of a half silvered glass plate with rulings made as close together as possible and yet have the silver strips continuous. As R. W. Wood and H. Rubens had succeeded in isolating long heat waves of the order of one-tenth of a millimeter from a Welsbach burner, this source was used. Since the rectification of short waves by a vacuum tube is limited by its physical dimensions[5] the crystal detector seemed to be the only rectifying device that might work. Therefore it was used in the two sets of apparatus that were made to find a current.

[4] Smith-Rose, Proc. Inst. Radio Eng., 17:434.
[5] Schreibe, A., Annalen der Physik, 73:54.

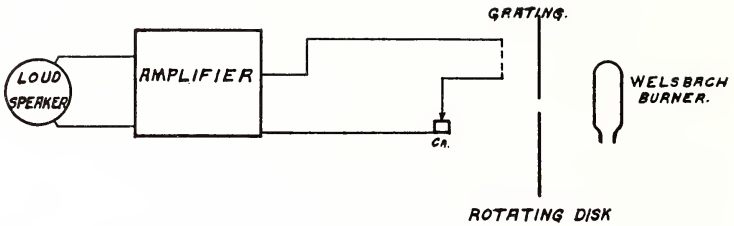

Fig. 4.

Figure 4 shows an audio frequency amplifier with an amplification constant of approximately 50,000 connected in series with the grating and the crystal detector. A rotating sector composed of a disk eleven inches in diameter and cut with twenty-four slots of about an inch width was placed between the Welsbach burner and the grating in order to modulate the wave with a frequency of about four hundred. The output of the amplifier was connected to a loud speaker. Although the alternating current hum in the speaker was not appreciable, no additional sound could be heard when the Welsbach burner was lighted and the disk rotated.

In the second piece of apparatus, a direct current amplifier using an FP 54 tube was connected to the grating and the crystal detector. This circuit was sensitive enough to pick up a potential as low as 10^{7} volts. It was necessary to shield all the apparatus except grid from the heat waves to avoid a spurious galvanometer deflection. Negative results were again obtained.

In the course of experimenting it was found that heat waves incident upon a crystal detector connected to a galvanometer showed a deflection that was opposite that of the spark waves. O. W. Pierce[6] made reference to this same condition and said it was observed with nearly all crystals. Evidently there are two ways that a crystal acts.

[6] Pierce, O. W., Physical Review, 28:153.

In conclusion it must be admitted that the essential results of this investigation are negative. However, this may be interpreted as positive evidence that the selected method of approach contained inherent limitations which defeated the purpose. That is, it would seem to be well established that a crystal detector used in a conventional radio circuit is not capable of detecting heat waves although it is good for spark waves in the region of four millimeter wave length. It is to be hoped that new methods may be devised for electrically detecting heat and, perhaps, light waves so as to establish experimentally the theoretical conclusion that these waves differ from Hertzian waves only in length.

I wish to thank Professor A. L. Foley, under whom this research was done, for his interest in the research and his valuable suggestions and Professor R. R. Ramsey for his aid.

Likenesses and Differences of Resonance Curves Produced by Damped Wave and Continuous Wave Transmitters

R. R. Ramsey, Indiana University

The resonance curve of a circuit is one which shows the relative value of the current in the circuit as the frequency of the impressed electromotive force is changed. Often the frequency of the e.m.f. is kept constant and the current is read while the capacity of the circuit is changed. These curves, in many cases, for all practical purposes, are the same as the true resonance curve. These curves, which are admittance curves, are often called resonance curves. Especially when the frequency n, as calculated from the formula $n = \frac{1}{2\pi\sqrt{LC}}$, is used instead of capacity as the abscissas.

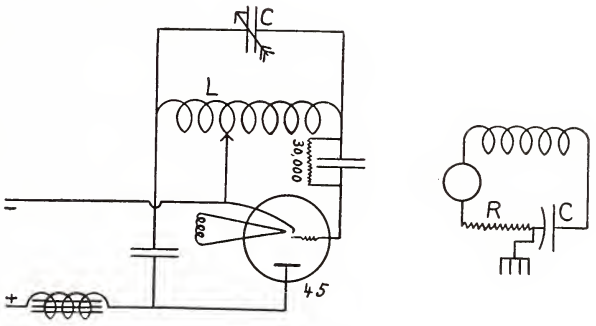

Fig. 1.

In Figure 1 the resonance curve is obtained by reading the meter in the wavemeter, while the frequency of the tube oscillator is changed by means of the variable condensers in the oscillator circuit. An admittance curve is obtained by reading the meter in the wavemeter circuit while the condenser in the same circuit is varied.

If the coupling is loose, i. e., the mutual inductance is small, both of these curves have one more or less sharp peak. If the coupling is close, or $M\omega > \sqrt{R_1 R_2}$ then the resonance curves have two peaks or humps. In the above formula M is the mutual inductance; ω is the angular velocity, or $\omega = 2\omega n$ where n is the frequency. R_1 and R_2 are the resistances of the primary and the secondary circuit, respectively.

If one uses the modern tube oscillator with pure d.c. potential on the plate of the tube, one has trouble in procuring the double humped curve. If one couples the secondary, or wave-meter, circuit, to the oscillator closely and varies the impedance of the wave-meter so as to make the current increase, the current in the wave-meter increases and

suddenly changes to a low value and decreases to zero as the capacity is changed in the same direction—capacity being increased, say. If, after the current has suddenly decreased to a low value, the dial is turned in the opposite direction so as to decrease the capacity, the current increases to some high value and then suddenly decreases, as in the first case. This is much as in Figure 2. If the generator is heterodyned

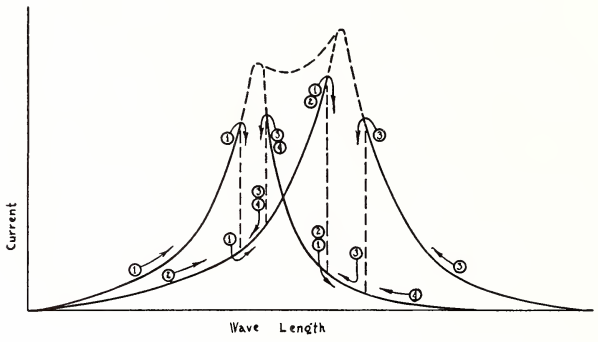

Fig. 2.

with some constant frequency, such as a broadcasting station, and the heterodyne tone is noted, there will be a sudden change of pitch when the circuit "flops." This shows that the frequency of the generator suddenly changes from one value to another. It seems that there are two possible frequencies at which the coupled oscillator system may oscillate, but it oscillates at any one time at one frequency only. It may suddenly change from one frequency to the other without any apparent cause.

If one uses a spark transmitter or damped wave and proceeds as above, a single hump is obtained with loose coupling, and a double humped curve is obtained with close coupling. This is illustrated in Figure 3. If a tuned link circuit is introduced between oscillator and

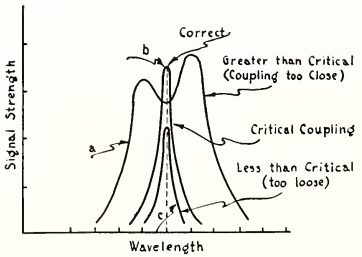

Fig. 3.

wave-meter and the coupling made loose, the position of the peak may be changed by detuning the link circuit a certain amount.

From this and other experiments with damped waves it seems that in an admittance curve or resonance curve the value of the ordinate at

any frequency shows the value of the current at the particular frequency in question. Thus, in Figure 3 it seems that we have maximum response at a frequency whose wave length is 300 meters, perhaps 1000 kilocycles, and also current at 297-303 meters, or at a frequency extending from 1010 to 990 kilocycles. In the case of the closely coupled circuit, there seems to be maximum current at about 298.5 and 301.5 meters.

This seems to justify the not unusual assumption that a coupled circuit produces two frequencies, neither of which is the frequency of the oscillator taken by itself. If, instead of the damped wave generator, one uses a C. W. oscillator and introduces a tuned link as in Figure 4, all admittance curves give peak response at the same frequency, namely, at the frequency of the oscillator. This shows that link circuits do not change the frequency of the oscillator, and the oscillator vibrates at one frequency only. This is true if the wave-meter is coupled loosely or closely to the link circuit. If the link is closely coupled to the oscillator, the frequency may change suddenly from one value to another, but there is only one frequency at any one time. If the link circuit (circuit 1 in Fig. 4) is loosely coupled to the oscillator, the wave-meter (circuit 2,

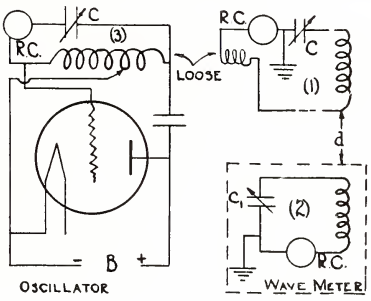

Fig. 4.

Fig. 4) being closely coupled to the link circuit and the link and wave-meter both tuned to the frequency of the oscillator, and a resonance curve is taken by changing the frequency of the oscillator, reading the ammeter in the wave-meter circuit, a douple humped curve is obtained. This shows that the closely coupled circuit is tuned for maximum response at two frequencies.

The apparent discrepancy between the continuous wave circuits and the damped wave is apparent if one remembers that a wave of varying amplitude is one whose frequencies are changing. Or a damped wave generator produces a band of frequencies, while a tube generator whose amplitude is constant generates current of one frequency.

In the early days of radio it was assumed that a spark station gave a single frequency, and apparently a closely coupled circuit produces two new frequencies. Too many physicists are still living in the spark station age.

In theoretical physics it is not an uncommon assumption that coupled circuits produce two frequencies. This, with the erroneous assumption that the sum of two sine waves produce combinational tones or side bands, has lead to many erroneous conclusions.

PROGRAM OF THE SECTION ON PSYCHOLOGY

Chairman: P. L. HIGHTOWER, Central Normal School

1. Objective data on Gestalt versus Connectionist. Frederick B. Knight, Purdue University.
2. Vision—A new concept. Frederick Booth, Michigan City.
3. The learning and forgetting of attitudes. H. H. Remmers, Purdue University.
4. An analysis of the conditioned responses in dogs, with special reference to the side of the body conditions. E. L. Walker and W. N. Kellogg, Indiana University.
5. On the relation of language to symbol usage. David R. Craig, Indiana University.
6. A comparative study of automobile braking reaction-time for visual and auditory stimuli. Frank R. Elliott, Indiana University.
7. Round Table Discussions.

General—What topics should constitute the beginning course in psychology? During what college year should this course be given? Chairman: A. R. Eikenberry, Manchester College.

Teacher-Training—Adequate psychological preparation for elementary and high school teachers. Chairman: Lars L. Hydle, Ball State Teachers College.

Clinical—A job analysis of the clinical psychologist: Where he works, what he does, and what constitutes desirable training for his work? Chairman: C. M. Louttit, Indiana University.

Industrial—Requirements for personnel work. Chairman: Edgar L. Yeager, Indiana University.

A. R. Eikenberry, Manchester College, was elected chairman of the Section for 1938.

ABSTRACTS

A new concept of vision based upon relativity. FREDERICK BOOTH, Michigan City.—According to the principle of relativity, time, velocity, and distance are not absolute, but purely relative. Vision is dependent on a combination of the three; omit one, and vision disappears. We estimate distance by the length of time required to move, at a certain velocity, from one of its extremes to the other. The judgment of time, velocity, and distance varies with the optical state of the observer's eye. If three persons, one myopic, one hyperopic, and one normal, all look at one thing, the three retinal images are different in size. Since judgment of distance depends upon the size of the retinal image, the estimates of these three observers must vary. As, with experience, they learn to estimate distances, they are really constructing measuring rods and

timepieces commensurate with their retinal images. Color is simply a mental interpretation based upon the velocities of the various waves. An individual timepiece and measuring rod must be applied to each color, and, consequently, color tint is a relative quantity. The correction of an optical defect changes the size of the image on the retina and necessitates the modification of units of time and length before distances can again be judged accurately.

The learning and forgetting of attitudes. H. H. REMMERS, Purdue University.—A series of experiments chiefly with subjects of high school age were designed to change attitudes toward such attitude objects as negroes, social insurance, capital punishment, labor unions, pupil self-government and toward certain issues related to conservation such as draining swamps, taxation for afforestation, clean farming, and government supervision of farming versus individual initiative in farming. The populations for the various experiments varied from 36 to 330. The effect of injecting defined social stimulus materials following the initial measurement of group attitudes was determined from paired group comparisons for central tendency and spread of measurements following the exposure of the experimental subjects to the social stimulus materials. The major findings all point to the relative ease with which attitudes of this sort can be changed and to their relatively high stability. Data concerning the relative stability of attitudes will also be presented. Some of the psychological and social implications of the studies are noted.

A Study of the Conditioned Response in Dogs with Special Reference to the Side of the Body Conditioned[1]

E. L. Walker and W. N. Kellogg, Indiana University

Introduction.—Studies in bilateral conditioning should have two general results. First, in the field of Psychology new facts may be uncovered to contribute to learning theory. Second, neurological theory may receive significant factual contributions.

Few studies have been made on bilateral conditioning. Gibson, Jack, and Raffell (2) have established cross-education in conditioned finger withdrawals, and subsequently Gibson and Hudson (1) succeeded in establishing bilateral transfer of the conditioned knee-jerk. The present writers have previously reported (4) a similar study in dogs in which original conditioning of the right foot and reconditioning and transfer conditioning of the left foot were compared, as were simple extinction and transfer extinction which took place in the right foot while the left foot was being conditioned.

Technique of conditioning.—The apparatus consisted of a wooden stock in which the animal was securely fastened so that each forepaw was strapped to a balanced lever, allowing recording of the flexion response to a height of about four inches. The animal wes separated from the experimenter by a one-way screen. The conditioned stimulus was an ordinary doorbell buzzer mounted on the experimenter's side of the screen, while the unconditional stimulus was a faradic shock administered to the dog's wrist through two metal electrodes and adjusted just strong enough to elicit a good flexion response.

The buzz was sounded for 2 sec. with the shock overlapping the last .2 sec. of the buzz period. If, before the shock was given, the animal raised his foot approximately 2½ inches, a mercury switch attached to the lever arm opened the circuit so that the animal escaped the shock. Reactions of both forepaws, the buzz, the shock, and the time in .2-sec. units were graphically recorded.

The stimulations were given in daily series of 20 each. The shock was omitted every tenth and twentieth trial. The criterion for conditioning was a daily series in which occurred 19 responses an inch or more in height. The dogs were first conditioned to lift the right forepaw to the buzz, were then unconditioned, and were then reconditioned. Immediately after the completion of the reconditioning, the shock was transferred to the left foot for the purpose of observing the bilateral transfer effects.

Three characteristics of the conditioned response under these conditions are to be considered in this paper, namely, the frequency, the height, and the latency. The frequency is the number of conditioned

[1] The research work, upon which this publication from the Indiana Conditioning Laboratory is based, was supported by a grant from the University.

responses of an inch or more in height taking place in each daily series. The height of the CR is the height of the foot at the point of introduction of the shock, whether or not the animal succeeded in escaping. The latency is the time between the beginning of the buzz and the beginning of the conditioned lift.

The progress of these measures throughout the different phases of the study as shown by their relation to the number of the series and the progressive relation of one to the other will be the form of the present analysis.

Comparison between different characteristics. Reliability coefficients were obtained by correlating the first half with the second half of each daily series. All correlation coefficients are obtained by the rank difference method and are uncorrected. Arithmetical averages of the coefficients have been given to facilitate comparison despite the statistical objections which are sometimes raised against such procedure.

TABLE I.—Reliability coefficients for the frequency, height, and latency of the conditioned flexion response for 3 dogs, in original conditioning of the right foot (O), reconditioning (R), and subsequent conditioning of the left foot (T).

		FREQUENCY		
DOG Nos.	1	2	3	Av.
O	.88	.63	.92	.81
R	1.00	.80	1.00	.93
T	.90	.80	.92	.87
Av.	.93	.74	.95	.87
		HEIGHT		
DOG Nos.	1	2	3	Av.
O	.79	.59	.60	.66
R	.50	1.00	.80	.77
T	.83	.80	.90	.84
Av.	.71	.80	.77	.76
		LATENCY		
DOG Nos.	1	2	3	Av.
O	.74	.30	.80	.61
R	1.00	.50	.80	.77
T	.77	.80	.90	.82
Av.	.84	.53	.83	.73

In general, reliability coefficients are high enough to justify their use. Coefficients for frequency are slightly higher than those for height and latency, but in the latter measures, a small but definite trend is observable throughout the training series, indicating a progressive increase in uniformity and consistency with training, no matter what the nature of the training.

Intercorrelations. The intercorrelations between the number of the series, the frequency, the height, and the latency are presented in Tables

II, III, and IV. It will be noted that in Tables II and III all coefficients are positive, while most of those in Table IV involving latency are negative. These values would indicate that amplitude and frequency are positively associated with the number of trials given and that latency stands in a negative relationship to the state of advancement. Irregularities in this table necessitate some explanation. It will be noted that the relationships are negative throughout in the case of one dog and are

TABLE II.—Correlations between the frequency of the conditioned response and the number of the series for 3 dogs, in original conditioning of the right foot, reconditioning, and subsequent conditioning of the left foot.

		ORIGINAL CONDITIONING		
DOG Nos.	1	2	3	Av.
	.90	.88	1.00	.93
		RECONDITIONING		
DOG Nos.	1	2	3	Av.
	.50	1.00	.95	.82
		LEFT-FOOT CONDITIONING		
DOG Nos.	1	2	3	Av.
	.93	1.00	.97	.97

TABLE III.—Correlations between the height of the conditioned response and the number of the series and between the height and frequency of the CR, in original conditioning, reconditioning, and subsequent conditioning of the left foot for 3 dogs.

		ORIGINAL CONDITIONING		
DOG Nos.	1	2	3	Av.
With number of series	.89	.83	1.00	.91
With frequency of response	.89	.92	1.00	.94
Average	.89	.88	1.00	.92
		RECONDITIONING		
DOG Nos.	1	2	3	Av.
With number of series	.50	.80	1.00	.77
With frequency of response	1.00	.80	.95	.92
Average	.75	.80	.98	.84
		LEFT-FOOT CONDITIONING		
DOG Nos.	1	2	3	Av.
With number of series	.83	1.00	.90	.91
With frequency of response	.93	1.00	.97	.97
Average	.88	1.00	.94	.94

TABLE IV.—Correlations between the latency of the conditioned response and the number of the series, between the latency and the frequency of the CR, and between latency and height for the CR, in original conditioning, reconditioning, and subsequent conditioning of the left foot.

ORICINAL CONDITIONING				
DOG Nos.	1	2	3	Av.
With number of series	—.69	.37	.80	.16
With frequency of response	—.71	.26	.80	.12
With height of response	—.63	.13	.80	.10
Average	—.68	.25	.80	.13
RECONDITIONING				
DOG Nos.	1	2	3	Av.
With number of series	—.50	—1.00	—1.00	—.83
With frequency of response	—1.00	—1.00	—.85	—.95
With height of response	—1.00	—1.00	—1.00	—1.00
Average	—.83	—1.00	—.95	—.93
LEFT-FOOT CONDITIONING				
DOG Nos.	1	2	3	Av.
With number of series	—.07	.75	.30	.33
With frequency of response	—.24	.75	.35	.29
With height of response	—.39	.75	.40	.25
Average	—.23	.75	.35	.29

negative in the reconditioning series for all three dogs. The fact that they are not so in the first training series for both the left and the right feet in two dogs is probably due (a) to the fact that the CR was unstable and irregular during the early trials and (b) to the possibility that the animals were more emotionally disturbed by the shock in the original conditioning and transfer conditioning than they were in reconditioning. This latter interpretation is supported by empirical observation during these phases of the study.

Hilgard and Marquis (3) reported this negative relationship between progress and latency in the case of the conditioned eyelid response. The irregularities indicated in this study may not have occurred in their work because of the difference in emotional effect between a puff of air on the eye, which they used, and the electric shock employed here.

Right-foot vs. left-foot responses. To discover whether there are characteristic differences between the CR movements which could be

related to the side of the body stimulated, the values in Table V were computed.

TABLE V.—Latency of the conditioned response in seconds for the original conditioning of the right forepaw (O), reconditioning (R), and subsequent conditioning of the left forepaw (T).

DOG		N	Av.	δ	δav.
	O	419	.912	.558	.0273
1	R	52	.692	.490	.0680
	T	87	1.082	.450	.0482
	O	171	.440	.436	.0333
2	R	56	.436	.386	.0516
	T	72	.628	.366	.0432
	O	58	.924	.460	.0604
3	R	74	.858	.458	.0533
	T	86	1.258	.392	.0423

DOG		Diff.	δdiff.	Diff. δdiff.
	OR	.220	.0732	3.00
1	OT	.170	.0554	3.07
	RT	.390	.0833	4.68
	OR	.004	.0614	.07
2	OT	.188	.0546	3.44
	RT	.192	.0673	2.85
	OR	.066	.0806	.82
3	OT	.334	.0738	4.53
	RT	.400	.0682	5.86

The average latencies in seconds, standard deviations, and standard errors of the averages are shown for O, R, and T in the case of each dog. It must be remembered in this connection that O and R involve the right side of the body while T involves only the left. From this table it may be seen that the critical ratios obtained are somewhat smaller between O and R than they are between R and T or O and T although the difference is a minor one in the case of Dog 1. It may also be seen that all three animals were slower to respond with the left than with the right forepaws.

It is probable that these differences are an outgrowth of an artifact of experimental procedure, namely, from what the authors have called *ambiguous conditioning*, a condition of the transfer series in which the dog apparently learns to lift the right foot and then the left foot in response to the buzz. This condition results from a continuation of the right foot lift even though the shock has been shifted to the left foot. The occurrence of this somewhat more complicated response may continue for only a few trials to as many as a hundred stimulations.

Further search for consistent differences between height, duration, and configuration of the right and left foot CR's has led to negative findings.

Summary. (1) Bilateral transfer of conditioning was experimentally observed in three mongrel dogs by means of the shock-buzz technique. The animals were trained to lift the right foot in response to the buzz, were unconditioned, were reconditioned, were then retained with the shock transferred to the left foot.

(2) The relationship between frequency, amplitude, and latency of the responses were considered in this report.

(3) Reliability coefficients for all these measures ranged from .30 to 1.00 with averages falling between .63 and .93.

(4) Latency was found to be the least consistent of the three, while frequency was the most consistent.

(5) Intercorrelations were reasonably high and positive between frequency, amplitude, and the stage of training, while correlations between latency and other measures were generally negative.

(6) Comparisons between responses of the left and right feet show a difference in latency which is large enough to be statistically reliable in most instances. No significant differences between the responses of the two sides were observed in duration, amplitude, or configuration.

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4. Kellogg, W. N. and Walker, E. L., 1938. Ambiguous conditioning, a phenomenon of bilateral transfer. Jour. Comp. Psychol. (In press.)

Auto Braking Reaction Times to Visual vs. Auditory Warning Signals[1]

FRANK R. ELLIOTT and C. M. LOUTTIT, Indiana University

The Problem

Do automobile drivers react significantly faster to sight or to sound warning signals? Are they able to shift the foot from accelerator to brake and set the brake more quickly at the sight of a red light or at the sound of an automobile horn? How do women compare with men in speed of reaction? How do the various occupational groups, professional people, farmers, laborers, and others compare in speed of braking reaction time? What correlations exist between speed and age, speed and experience? These are questions which the present experiment seeks to answer.

Moss and Allen in 1925 reported on the personal equation in driving. Forbes, Moede, Sandor, Lauer, and DeSilva have studied various aspects of auto drivers' reactions, but the available literature does not seem to offer direct evidence on modes of stimulation, on sex, and on occupational differences.

These questions take on special importance at this time when highway safety is recognized as a problem of first interest to the nation. No one escapes the danger. The problem is of interest also in view of current campaigns against noise, which in some cities have resulted in ordinances designed to reduce the use of automobile horns and other sound signals. Finally, the present experiment is one of a series by Elliott which seeks to reveal the relative effectiveness of visual vs. auditory stimulation on such human reactions as attention to advertising, memory for advertising trade names, and comparative inquiry and enrollment responses to printed literature and the spoken word.

Procedure

The present investigation was carried on at the Indiana State Fair in September, 1936, with Dr. Louttit as the chief experimenter. He was assisted by Lt. Don L. Kooken, of the Indiana State Police; Officer Freed, of the State Police; and Dr. Elliott. Zenon Szatrowski handled the statistical compilations.

A Ford coupe was parked at a conspicuous location in the Indiana University Exhibit Building, where several thousand visitors passed daily. Mimeographed blanks describing the experiment and asking for the age, sex, driving experience, occupation, and home community of each subject were made available to persons who asked to take the test. After filling out these blanks and hearing the explanation of procedure, each subject took the driver's seat in the car, held the accelerator half way to the floor with his right foot, and at the appro-

[1] This experiment was reported by Frank R. Elliott Nov. 5, 1937, before the Indiana Academy of Science and by C. M. Louttit June 19, 1937, before the Western Psychological Association.

priate signal shifted his foot to the brake pedal and pushed it down.

Reaction times were measured on a calibrated Bergstrom chronoscope placed at the experimenter's eye level. The experimenter controlled both sound and sight signals from his control board. The magnetic clutch of the chronoscope was activated through the stoplight switch of the automobile. The time measured was that from presentation of the stimulus to that when the brake pedal had been depressed and the stoplight switch had been closed. Each subject was given three trials with the sight and three trials with the sound signals in a standard chance order. No suggestion was made as to which signal would be given; the subject was warned to respond to either. The visual stimulus was a 100-watt bulb mounted on the wall directly in front of the driver's seat. The auditory stimulus was an auto horn suspended under the hood of the car, in such a way as to prevent vibration being felt by the subject.

Results

About 700 people took the test over the period of one week at the Fair. Some record blanks were found incomplete, with the result that the number of subjects varies slightly in the different situations. Average time for 697 subjects in the visual situation was .524 seconds, with a range from .350 to .850 seconds. Average time for 687 subjects in the auditory situation was .514 seconds, with a range from .350 to 1.150 seconds.

Table I shows the averages on the three trials for each mode by each subject, with the standard error of the distribution, the absolute difference between visual and auditory scores, and the critical ratio indicating the reliability of the difference.

Table II shows similar material for the two sexes.

Table III shows the distribution of reaction times averaged for three trials, with the modal group requiring .400 to .499 seconds for both visual and auditory modes.

Table IV shows average reaction times by occupational groups.

Table V compares average reaction times of the various groups and shows the reliability of the differences.

Table VI shows correlation between reaction time, age, and driving experience of the subjects.

TABLE I.—Reaction Times to Visual vs. Auditory Signals—All Subjects

Modes of Present.	Number of Subjects	Av. Times (Seconds)	Sigma Dist.	Diff. in Times	Critical Ratio
Visual (Red Light)	697	.524	.083		
Auditory (Auto Horn)	687	.514	.091		
Vis. vs. Aud.				.01 Sec.	5.26

TABLE II.—Reaction Times of Males and Females

Sexes	Modes	Number Subjs.	Av. Times (Seconds)	Sigma Dist.	Diff. in Times	Critical Ratios
Females	Visual	98	.563	.101		
Males	Visual	545	.520	.079		
Females vs. Males	Visual				.043	4.00
Females	Aud.	98	.548	.107		
Males	Aud.	545	.508	.088		
Females vs. Males	Aud.				.040	3.48

TABLE III.—Reaction Times of Occupational Groups—Both Sexes

Occupational Groups	Number Subjs.	Visual Mode		Auditory Mode	
		Av. Times (Seconds)	Sigma Dist.	Av. Times (Seconds)	Sigma Dist.
Professional	40	.502	.048	.491	.069
Semi-Prof.	28	.517	.022	.500	.080
Students	201	.517	.085	.492	.088
Salesmen	40	.533	.075	.526	.096
Clerks	27	.549	.089	.528	.075
Truck or Taxi Drivers	34	.517	.065	.497	.057
Skilled Labor	95	.514	.090	.497	.091
Farmers	91	.540	.030	.533	.090
Common Labor	103	.546	.085	.537	.127

TABLE IV.—Group Differences in Reaction Times—Both Sexes

(Of 36 Possible Comparisons of Occupational Groups, Only the Following Had Statistical Significance)

VISUAL MODE

Group Comparisons	Time Differences (Seconds)	Critical Ratios
*Professional vs. Farmer	.038	5.3
Professional vs. Common Laborer	.044	4.1
Semi-Professional vs. Farmer	.023	4.6
Semi-Professional vs. Common Laborer	.029	3.2
Student vs. Farmer	.023	3.3
Student vs. Common Laborer	.029	2 9
Skilled Laborer vs. Common Laborer	.026	2.9

AUDITORY MODE		
*Professional vs. Common Laborer	.046	3.0
Student vs. Farmer	.041	2.9

*The first-named group in each pair shows the lower reaction time.

TABLE V.—Correlation Between Reaction Time, Age, and Driving Experience

Correlations	Visual Mode		Auditory Mode	
	r	PE	r	PE
Time (1) and Age (2)	+.37	±.022	+.37	±.022
Time (1) and Experience (3)	+.09	±.026	+.24	±.025
Time (1) and Age (2) With Experience Partialled Out ($r_{12.3}$)	+.38	±.022	+.29	±.024
Time (1) and Experience (3) With Age Partialled Out ($r_{13.2}$)	—.14	±.026	+.04	±.026
Age (2) and Experience (3)	r = +.556			

TABLE VI.—Distribution of Reaction Times Averaged from Three Trials

Reaction Time In Milliseconds	Visual Mode	Auditory Mode
300–399	7	23
400–499	299	329
500–599	286	246
600–699	84	64
700–799	15	18
800–899	6	4
900–999	0	1
1000–1099	0	1
1100–1199	0	1

Summary

This investigation of automobile braking reaction time for nearly 700 subjects indicates that it takes about 1/100 of a second less time to set the brake following an auditory stimulus (sound of a horn) than to set the brake following a visual stimulus (sight of a red light). The average auditory time is .514 seconds; visual time .524 seconds. The difference is reliable, with a critical ratio of 5.26. Differences between visual and auditory reaction times are all of the same order of magnitude in the various sub-groups. The subject who reacts rapidly by one mode also tends to react rapidly by the other, as indicated by a positive correlation of .84 between visual and auditory reaction times.

Women require about 4/100 of a second more time to set the brake than men, either following visual or auditory stimulation. The differ-

ence is reliable in each case, with a critical ratio of 4.00 in the case of visual presentation and 3.48 in the case of auditory presentation.

The lower the occupational group on the Barr scale, the longer its reaction time tends to be. Thus, the time for common laborers is .546 seconds by visual mode, while the time for professional people is .502 seconds by the same mode. Common laborers require .537 seconds by auditory mode, while the professional group reacts in .491 seconds by auditory mode.

Truck drivers and taxi drivers as a group had a faster reaction time than their rating on the Barr scale would indicate. Their time, however, is not much faster than the average time of all subjects.

No significant difference was found between the average reaction times of 262 subjects living in rural areas or in villages of less than 2500 population and 433 subjects living in urban areas. Rural subjects were faster than urban subjects by .006 seconds in the visual tests, while urban subjects were faster by .007 seconds in the auditory trials.

Braking reaction time tends to increase slightly with age, as indicated in Table V by a positive correlation of +.37 between reaction time and age. The correlation between time and experience drops to +.09 for visual mode and +.24 for auditory mode. With the experience factor held constant, the correlation between time and age is +.38 for visual and +.29 for auditory presentation. With the age factor partialled out, the correlation between time and experience drops to —.14 for visual mode and +.04 for auditory mode. From these correlations it appears that age has somewhat more significance in braking speed than does experience. This finding is corroborated in the average times of taxi and truck drivers. They rank high in experience but do not react much more quickly than the average subject.

Discussion

While the difference of 1/100 of a second may seem an insignificant advantage in favor of the auditory mode, it is to be remembered that an automobile traveling at 60 miles per hour will continue 44 feet before the average driver of our experiment can even set the brake. After that, experiments have shown, the automobile normally will continue another 198 feet before the mechanical action of its brakes can bring it to a full stop. Thus, any fraction of a second saved in driver's reaction time may easily mean the difference between life and death.

This would be particularly true of automobiles coming head on at high speed, where a listless or drowsy driver might be brought to his senses and to a foot-braking or hand-steering reaction just in time to avoid collision. Even slightly speedier braking reaction might avert crashes from cars backing into each other. Split-second reaction either on the part of driver or pedestrian often saves human life.

It might seem at first glance that the reaction time advantage of sound over sight would be offset by the slower speed of sound. In the 1/100 of a second quicker reaction time which our subjects showed for sound signals, sound would travel only about 11 feet; whereas, light's speed would be practically instantaneous. On the other hand, the

chemical processes of the visual receptors require more time for the sensation of seeing than the physical processes of the auditory receptors require for hearing.

A main factor in favor of sound is that it is non-directional, while sight requires more direct fixation. Further, warning light signals are often confused with advertising signs, Christmas decorations, and other ornamental lighting, while the sound of an auto horn is rather distinct as a warning signal.

In spite of city ordinances against noise, there still seems to be a definite need for the automobile horn and the policeman's whistle. Sound signals bring faster reaction than sight signals in our field tests, just as sound stimuli have brought faster time than sight stimuli in the simple reaction time tests of the psychological laboratories.

PROGRAM OF THE SECTION ON ZOOLOGY

Chairman: W. P. ALLYN, Indiana State Teachers College

1. Symposium—A practical wild animal conservation program for Indiana.

   Possibilities for conservation in an agricultural state. Kenneth M. Kunkel, State Conservation Department.

   The problem of migratory animals, particularly birds. Daniel H. Janzen, U. S. Biological Survey.

   Conservation from the naturalist's point of view. Marcus W. Lyon, Jr., South Bend.
2. The accumulated sediment in Tippecanoe Lake and a comparison with Winona Lake. Ira T. Wilson, Heidelberg College, Tiffin, Ohio.
3. A method for the preparation of skeletal material. J. P. Scott, Wabash College.
4. Heldout, a recessive wing mutation in Drosophila. Edward Novitski and S. A. Rifenburgh, Purdue University.
5. Ailanthus altissima as a honey plant. Ben H. Smith, Indiana State Teachers College.
6. New Mexican gall wasps (Hymenoptera, Cynipidae)—III. Alfred C. Kinsey, Indiana University.
7. Notes on bionomics of roaches inhabiting homes. George E. Gould and Howard O. Deay, Purdue University.
8. Insects of Indiana for 1937. J. J. Davis, Purdue University.
9. Cercariae of Indiana—1. A preliminary note on larval trematodes from McCormick's Creek with descriptions of three new species. R. M. Cable, Purdue University.
10. A note on a phyllodistome trematode form the urinary bladder of the Miller's Thumb, Cottus sp. Edwin B. Steen, Purdue University.
11. The absorption of colloidal carbon from the body cavity of Ammocoetes. Theodore W. Torrey, Indiana University.
12. Zoology laboratory without drawings or written reports. S. A. Rifenburgh, Purdue University.
13. A cat with an "upside-down" stomach. S. A. Rifenburgh, William P. Lawson, and Ralph P. Ogden, Purdue University.
14. Respiration studies with fresh-water molluscs: I. Oxygen consumption in relation to oxygen tension. William A. Hiestand, Purdue University.
15. Respiration studies with fresh-water molluscs: II. Oxygen consumption in relation to H-ion concentration. William A. Hiestand and Doris M. Hale, Purdue University.
16. Some observations on the reproductive cycle of a common land snail, Vallonia pulchella Mull; influence of environmental factors. Margaret Esther Whitney, Central Normal College.
17. The neural scute row in Testudinata. Chapman Grant, San Diego, California.
18. Lasiurus cinereus. S. E. Perkins III, Indianapolis.

19. Preliminary survey of surviving Testudinata in Vigo County and immediate vicinity. William Hopp and W. P. Allyn, Indiana State Teachers College.
20. Preliminary survey of surviving species of Caudata of Vigo County and vicinity. Clarence Shockley and W. P. Allyn, Indiana State Teachers College.
21. Staining methods for protozoa. W. P. Allyn, Indiana State Teachers College.

H. G. Nester, Butler University, was elected chairman of the section for 1938.

ABSTRACTS

Ailanthus altissima as a honey plant. B. H. SMITH, Indiana State Teachers College.—Because of the prevalent opinion among beekeepers that the staminate flowers of Ailanthus, commonly known as "tree of heaven," are the source of much inferior honey, a controlled experiment was made to determine the facts. A hive of bees was placed in a greenhouse, which was well screened to limit their range, and allowed to use all the honey left in the hive. Fresh flowers of Ailanthus were then introduced for a few days, and a small amount of honey was produced. This probably came mostly from the flowers, but a few bees were found working the glands at the base of the leaflets. The pure Ailanthus honey did not have the objectionable taste, odor, or color usually attributed to it. A number of persons, including an experienced beekeeper, who were asked to pass judgment on several samples of honey, including this produced under experimental conditions, showed no consistent aversion to honey from Ailanthus. From this experiment it is concluded that Ailanthus is probably not responsible for the objectionable qualities that have been ascribed to it.

Cercariae of Indiana—1. A preliminary note on larval trematodes from McCormick's Creek with descriptions of three new species. R. M. CABLE, Purdue University.—A survey of the trematode parasites of aquatic gastropods from McCormick's Creek has yielded nine species of cercariae. From *Goniobasis sp.*, the following are reported: *Cercaria Macravestibulum obtusicaudum* Mackin, 1930; C. *Proterometra macrostoma* (Faust, 1918); C. *megalura* Cort, 1914; *C. kentuckiensis* Cable, 1935; an unidentified xiphidiocercaria of the "Virgula" type; *C spinosostoma* n. sp., *C. trichocephala* n. sp., and *C. abbrevistyla* n. sp. A large xiphidiocercaria from *Physa* sp. has not been identified. *C. spinosostoma* is the second freshwater species of pleurolo-phocercariae to be described from the United States. In addition to the characteristics of the group, *C. spinosostoma* is distinguished by the following specific characters: average body length 0.225 mm., measured from living material under light coverglass pressure; entire body spinose; tail 0.66 mm. long, provided with a fin-fold extending along dorsal side, around distal tip, and 2/5 the distance to the base on the ventral side; left eye-spot double;

oral sucker with three transverse rows of large spines on the anterior edge of the dorsal wall; acetabulum lacking; 14 penetration glands. *C. trichocephala* and *C. abbrevistyla* make a total of five species of freshwater cotylocercous cercariae reported from the United States. Both species have the general characteristics of the "Linearis" group, *C. trichocephala* being distinguished by the following specific features: average body length 0.23 mm., body aspinose; average length of tail 0.041 mm.; numerous sensory hairs at anterior end of body, a single lateral pair at a level just posterior to the pharynx; stylet 0.019 mm. long, asymmetrical in lateral aspect; inner surfaces of oral sucker and acetabulum spinose; intestinal ceca present; excretory formula 2(2+2+2+2). *C. abbrevistyla* resembles closely *C. trihoderma* Cable, 1935, but with a very short stylet (0.0083 mm.), that of *C. trichoderma* being much longer (0.013 mm.) and very different in shape.

A note on a phyllodistome trematode from the urinary bladder of the Miller's Thumb, Cottus sp. EDWIN B. STEEN, Purdue University.—Approximately 11% of the Miller's Thumbs collected in the vicinity of Lafayette, Indiana, were found to harbor a species of Phyllodistomum in the urinary bladder. A maximum of five worms was recovered from a single fish. The worm has the general characteristics of the genus and may be distinguished by the following specific characters: body length, 2.45-3.14 mm.; width of posterior portion, 1.39-1.97 mm.; diameter of oral sucker, .22-.29 mm.; diameter of acetabulum, 0.37-0.54 mm. Testes obliquely situated, 0.63-0.73 mm. in length and 0.29-0.44 mm., in width; ovary lobed, 0.31-0.34 mm. in length and 0.18-0.29 mm. in width. Vitellaria lobed, much reduced in size. Pharynx and cirrus pouch absent. Average egg size, 0.029x0.041 mm. Posterior portion of body discoidal in shape with its lateral margins thrown into seven folds, three lateral pairs and a single median dorsal fold at the extreme posterior end.

The absorption of colloidal carbon from the body cavity of the Ammocoetes. THEODORE W. TORREY, Indiana University.—Colloidal carbon injected into the coelom of the larval lamprey, Ammocoetes, is taken up directly by the pronephric tubules. Due to the absence of nephrostomes, the mesonephric tubules do not function in a similar way. The tubules of neither show any intracellular deposition of carbon. The reticular elements which support both these kidneys exhibit pronounced phagocytic and hemocytopoietic activity. Carbon in either a free or included form reaches all the other organs as a result of both direct invasion and secondary distribution by the vascular system. The liver is the only organ whose vascular endothelium exhibits cytopoietic properties. To the diffuse spleen as a site of blood cell formation should thus be added the reticular tissue of the pronephros and mesonephros and the vascular endothelium of the liver. Playing a minor role in a similar way are the intestinal mucosa in addition to that in the typhlosole and the spongy tissue dorsal to the neural tube.

Zoology laboratory without drawings or written reports. S. A. RIFENBURGH, Purdue University.—A method of teaching comparative anatomy is described in which drawings and written reports are replaced

by oral reports and demonstrations. The student studies the material as directed until he thinks that he has mastered the problem. Then he asks for opportunity to report on his work. The results obtained with the method thus far are attributed to the more economical use of time and the shifting of responsibility from the instructor to the student.

Lasiurus cinereus. S. E. PERKINS III, Indianapolis.—On August 30, 1937, at 11:30 a.m., at Lake Maxinkuckee in Marshall County, Indiana, there fell into the water a living male adult specimen of *Lasiurus cinereus*. It was a sunny day, and the temperature at noon was 90°. The bat lay stretched out on the water while approached and did not swim. It fell vertically, balancing in the manner of a chimney swift entering a chimney with wings partially extended, and where the bank of the lake was forested. It hit the water some fifty feet from shore and slightly beyond the extent of overhang of longest tree limbs over the lake.

The bat was captured and measured by me while alive showing: spread, 13¼ inches; length, 4¾; tail, 2½ inches.

This species, the Hoary Bat, is the largest in Eastern United States. Identification was confirmed by Dr. Marcus Ward Lyon, Jr., author of "Mammals of Indiana." Dr. Lyon reports that this is the third Indiana specimen and the first from Marshall County.

It is the first Indiana specimen photographed while living. It died an hour after its experience in the water and a study skin was made of it. The body was not plump.

Possibilities for Conservation in an Agricultural State

KENNETH M. KUNKEL, Department of Conservation

I represent that division of Indiana's state government known as the Department of Conservation and charged with administration of state laws relating to the conservation of natural resources. Created in 1919 and made part of the Department of Public Works by the 1933 Reorganization Act, functions of the department are administered by a Commissioner who is appointed by and responsible to the Governor.

Continuing today as established, the department has six co-operating subdivisions: Division of Geology, Division of Entomology, Division of Forestry, Division of State Parks, Lands, and Waters; Division of Engineering, and the Division of Fish and Game, of which I am the Director. Duties and activities of these divisions are so varied that it is not possible, in the time at my disposal, to review their operations, and my subsequent remarks will be confined to the Division of Fish and Game.

Powers, duties, and functions of this Division, as prescribed by the Indiana General Assembly, are, in brief: to promote beneficial fish life by improvement of lakes, streams, and watercourses and by artificial propagation; to preserve, propagate, and introduce beneficial species of game and game birds and song birds; to acquire and operate properties for fish and game propagation; to enforce such regulatory laws as may be enacted for preservation and protection of wildlife; and, to encourage, by education and organization, the formation of associations to further this program.

Out of the privations and sorrows of the depression has come the determination of the people of this country that a sensible and permanent national policy of restoration and preservation of our natural resources is necessary. Our resources of land, forests, and wildlife are so closely allied that to improve one is necessarily beneficial to the others. The replanting of forests and their protection from fire; the sensible management of land for agriculture, to prevent erosion and depletion of fertility; and a comprehensive plan of water conservation, both to conserve water in times of drought and to prevent wasteful floods, all have effects equally beneficial to the habitats and food supply of wildlife.

In this planning for the present and the future, the farmer occupies a peculiar and very important position. Due to the small acreage of public land in Indiana, it is to the private landowner that we must turn. Always a sportsman and by reason of his occupation a conservationist, the landowner must also keep in mind some material aspects of conservation. Seldom prosperous year after year, with taxes always a burden and oftentimes with his land heavily mortgaged, the farmer is entitled to be relieved of the major cost of restoration work. With his land constantly overrun by all of us with our inherited tendency to destroy wildlife, it is our responsibility to find easy, economical, and efficient means whereby wildlife can be restored to normal numbers.

Wonderful results have been accomplished by game management in areas where the population is small or in areas where hunting is restricted to the few. In our state, where everybody hunts, all of our land must be made to produce a capacity crop of wildlife to take care of our requirements. In future years heavier demands will be made upon our land for wildlife.

It is known that the number of sportsmen is constantly increasing, making further demands upon the area available for fishing and hunting. This necessitates, of course, that we make the available area more productive of fish and game. To do this, it is absolutely necessary that we receive the co-operation and support of the landowner who oftentimes in the past has been abused, his property destroyed and his feelings outraged by the careless sportsman who thus destroyed the sport of many of his brothers for the future. I am glad to say that this feeling is not as prevalent in our state as in many other sections of the country. In this country we have a system, the basis for which is the right of private ownership. By that right, the landowner controls who and who shall not enter upon his grounds and, within the boundaries of that right, are we dependent upon the landowner for the enjoyment of the sports of fishing and hunting.

There is another basic provision in our general order, which is that the right and title to all wildlife remains in the state. As a department of the state administration, and representing the people of the state, the custody of the fish and game in Indiana is in our care. We hold this right in trust for the benefit of all of the people of the state. We extend the privilege for a fee to a certain class of people to take fish and game at certain times of the year, under certain rules and regulations. This is a privilege enjoyed by all who pay a license fee, and the proceeds received by the department from the sale of these licenses constitute our entire revenue to replenish and protect the wildlife of the state. I want to emphasize the fact that the Division of Fish and Game receives no money whatsoever from the general funds of the state but conducts all of its operations through revenue derived from the sale of fishing and hunting and trapping licenses.

We have approximately 350,000 license-buyers in the State of Indiana. We have no public hunting area in the state. It is evident, then, that the license-buyers must enjoy their sport upon privately owned lands, which means that under our laws permission to enter upon the lands of another is necessary. It is our responsibility to educate the license-buyers to follow the law in securing permission to hunt and fish, to comply with the rules of good sportsmanship, and to protect the supply of both game and fish. It is our responsibility to regulate hunting and fishing for the benefit of all and to see that both fish and game be taken in such numbers and at such times as to prevent depletion. To maintain the supply of game, we must furnish it with a suitable place to live, which means that we must preserve a sufficient breeding stock at the end of each open season and see that it is properly taken care of during the winter and that its habitat is of sufficient quality that the game is enabled to propagate and exist naturally.

It is only reasonable to assert that, because the license-buyers of the state pay for the protection, preservation, propagation, and introduction of wildlife, their desires and wishes should be considered in the management of the wildlife resources of the state. This department is the only protective agency of the state administration, not only for the protected species of game birds, animals, and fish, but also for the non-game species.

In Indiana, I hope it will always be possible for the man who lives in the city to find a place to hunt in the country. To destroy free hunting in our state would be to end a period in our history under which the finest type of citizenship was developed. To restrict the sport of hunting to a favored few, who, by accident of birth or special advantages, could either possess land or buy the privilege of hunting upon such land, is a condition which I should certainly dislike to see imposed upon Indiana. Free hunting can be continued in our state if there is co-operation between the man who wants to hunt, the man who owns the land upon which the game is found, and the state as represented by the Conservation Department, which owns the game that is hunted. We do not encourage the posting of land, but we do encourage and should insist upon every sportsman's asking permission before entering upon the lands of another. It is easy to influence the farmer against the "city sportsman," who dresses in fine clothes and carelessly claims for his own that of which the farmer feels he should have a share. It has been the history of this country that class and professional prejudice is easily aroused. That is the reason that the organization of farmer groups is easy, especially when the sportsmen as a class are described as destroyers of wildlife. The sportsman is entitled to the credit of being the protector of wildlife, as it is he who supports the only protective agency for wildlife in the state, and it is he who pays for the winter feeding, the refuges, the restocking program, and for the new species which are introduced in our state.

To encourage landowners to post their land deprives the real sportsman of the opportunity of recreation and does not prevent the violator from continuing as he always has in the past. We are thoroughly sold on our educational campaign, and no one is working harder than this department to bring the landowner and the sportsman together. We have thousands of farmers enrolled in our conservation clubs and taking an active part in accomplishing our conservation program for this state. This educational campaign and the idea of working together is much better and productive of more lasting results than could be accomplished by the prohibiting of hunting.

The farmer should be made to see that he holds in his possession a natural resource which is the common property of all the people, that he controls the enjoyment of a recreation that can be obtained in but one way, that the need for recreation extends to all the people, and that he has no right to withhold the enjoyment of that form of recreation. Both the sportsman and the farmer need education designed to promote the mutual understanding so necessary for a close co-operative agreement. Each needs the other, and each has a responsibility in this complex social order of ours.

Some of the factors which have been responsible for the decrease of our game are: first, more intensive cultivation with the clean fence rows and the utilization of waste areas which accompany it; second, over-grazing and spring burning of roadsides, fence rows, and so forth, which destroy nesting cover; third, the destruction of our marshes and water areas for our waterfowl and the pollution of our streams and lakes for fish life; and fourth, of course, the ever-growing number of hunters and fishermen. Some of the above can be corrected, but we cannot hope to restore primitive conditions nor ever again to have the abundance of game and fish life that we once had. None of us wish to go back and lose the advantages of intensive cultivation of land with its attending prosperity and rise in the standard of living for those who till the land. We hope by education to merge the present day methods of farming with a few simple practices of game management in such a way that both will benefit.

In planning management of any area, it is necessary to keep in mind that the expenditures for any plan must not be excessive, and the plan must not conflict with the successful farming of the area. The actual mechanics of game management are simple. All authorities agree that the destruction of the natural habitat of game is largely responsible for its decrease. The improvement of that habitat, so that a given area will produce more game, is the result sought by game management. Perhaps it is a misnomer to call it game management; it should be called land management or utilization. The best game management agency is nature, and she will quickly restore to game fertility land which is not now productive of wildlife. In all game management projects we should try to work with nature instead of against her.

The Accumulated Sediment in Tippecanoe Lake and a Comparison with Winona Lake

Ira T. Wilson, Heidelberg College

1. Introduction

This paper, which describes the amount and distribution of the accumulated sediment in Tippecanoe Lake, is a sequel to a similar report made on Winona Lake (Wilson, 1936). A comparison of the two lakes is made, and some suggestions are offered to explain the distribution of the sediment.

The study is based upon 103 borings (Fig. 1) penetrating to the original bottom of the lake and distributed so that twelve cross section profiles (Fig. 2) could be made. A contour map of the original bottom (Fig. 3), constructed from the data, together with a 5-foot contour map of the present basin, formed the basis of the calculations of the volume of sediment.

Tippecanoe Lake contains three "marl islands" (Fig. 1). A study of these, together with that of two similar islands in Winona Lake, make it practically certain that the interpretation given in the report on Winona Lake is correct.

Chemical analyses of the samples of the sediment in the lake are being made. A report of this aspect of the work will be made in the near future by David F. Opdyke and the author.

2. Acknowledgments

The author is especially indebted to the late Dr. Will Scott, director of the Indiana University Biological Station, for suggesting and encouraging the work on Tippecanoe Lake and for furnishing the equipment to carry it on. Acknowledgment is due, also, to Mr. Bruce Pierce, who donated the use of his property and splendidly equipped boat, repair shop, and garage. Two students, David F. Opdyke and Frederick J. Ludwig, and the writer's son, Robert Wilson, helped in the field work. The author is indebted also to James H. Kranich, who has done much of the work on the maps and the calculations contained in the tables. The writer's faculty colleagues, Dr. Jesse Pierce and Professor G. A. Stinchcomb, have discussed the technique of the study of the data with him many times and have made many useful suggestions.

3. General Description of Tippecanoe Lake

Tippecanoe Lake is located in Kosciusko County, Indiana, about 10 miles northeast of Warsaw. It lies in sections 1, 11, 12, T. 33 N., R. 6 E, and sections 6-9, 16-18, T. 33 N., R. 7 E. By interpolation of a description by Leverett (1915, pp. 138, 140), it seems that the lake lies on the outer border of the east end of the New Paris moraine of the Saginaw lobe, near the union of this moraine with the Pakerton moraine (Malott, 1922, p. 118). A broad gravel plain extending from the west end of the lake several miles is apparently outwash from the New Paris moraine. The lake is long and narrow with high (20-40 feet) ridges along each side. This fact caused Blatchley and Ashley

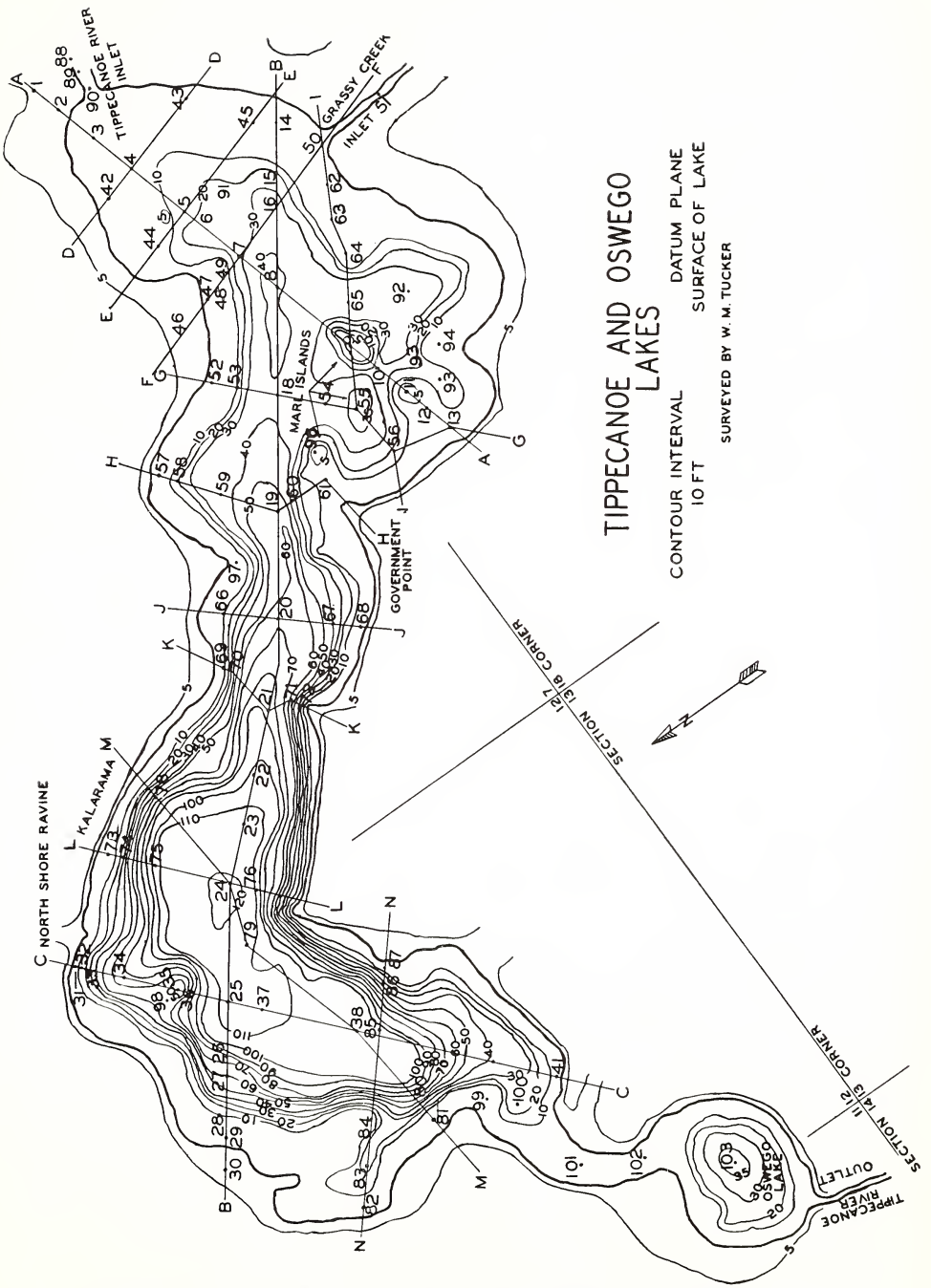


Fig. 1. Contour map of Tippecanoe Lake showing locations of the borings. The 5-foot contour lying outside the shore is assumed to be the original lake shore. (Note the following errata in cut: boring No. 39 should be inserted on CC at contour 80 and 77 on LL at contour 40; No. 93 should be 95.)

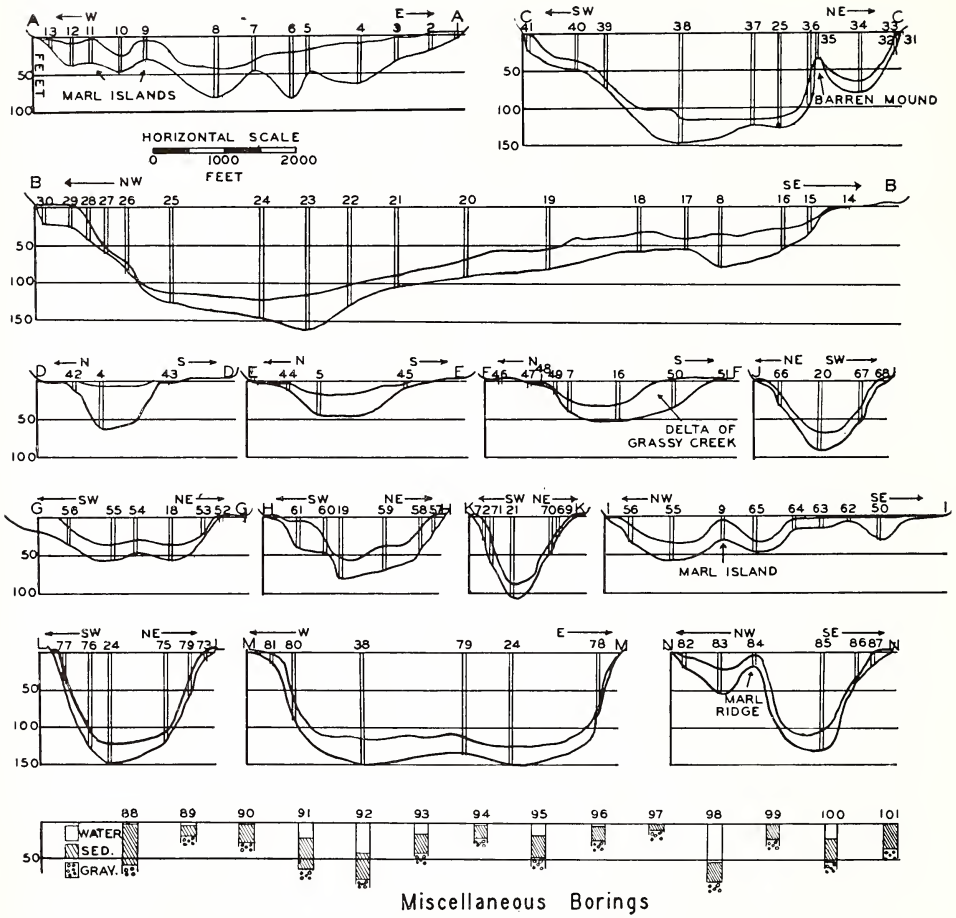


Fig. 2. Profile diagrams of the original (lower line) and the present lake basins (upper lines). The space between the lines represents the sediment in the lake. The vertical scale of the diagrams is ten times the horizontal. Borings are shown as double vertical lines and are numbered as in Figure 1. (No. 79 in profile LL should be 74.)

(1900, p. 35) to classify Tippecanoe as a channel lake, but it seems more likely that it is of the kettle-hole type lying in the outwash plain.

The greatest present depth of the lake is 123 feet; it is the deepest lake in the state. Its present basin has an area of 707 acres. There are two inlets (Tippecanoe River and Grassy Creek) and one outlet. Since both entering streams drain large morainic areas containing many lakes and swamps and are interrupted in their courses many times by lakes, they have a relatively constant and regular flow and carry a very light load of sediment. Fluctuations of 4 feet in the level have been reported by local residents.

The thermocline on August 12, 1912, was between 20 and 30 feet as inferred from a temperature series reported by Scott (1916, p. 25). The pH of the bottom water was 7.2 on July 12, 1937.

The elongated shape of the lake, its great depth, and its position in the main channel of the river, with a narrow shelf zone at the deep west end and a broad shelf zone at the shallow east end (Fig. 1), made it seem likely, at the outset of the work, that this would be a good basin for comparison with Winona Lake already studied. The latter lake has about the same area but is more nearly circular and less diversified in the shape of the basin; like Tippecanoe Lake it has two inlets and one outlet, but it is not in the main channel of a river. Winona Lake has a much smaller drainage area than Tippecanoe Lake, but its entering streams have been relatively less interrupted by flowing through other lakes. Both have their long axes in the direction of the prevailing winds. The original shore line of Winona Lake is 5.1 miles (.000777 ft. per sq. ft. of area) as compared with 6.8 miles (.000923 ft. per sq. ft.) for Tippecanoe Lake.

All the sediment in Tippecanoe Lake is marl except a thin layer over the emerged zones between the original and present shores, which is peat. Blatchley and Ashley (1900, p. 194) report as an average sample along the south shore near Government Point the following analysis:

Calcium carbonate ($CaCO_3$)	91.02%
Magnesium carbonate ($MgCO_3$)	2.28%
Iron oxide (Fe_2O_3)	0.29%
Calcium sulphate ($CaSO_4$)	0.05%
Insoluble (Silica, etc.)	2.92%
Organic matter	2.10%

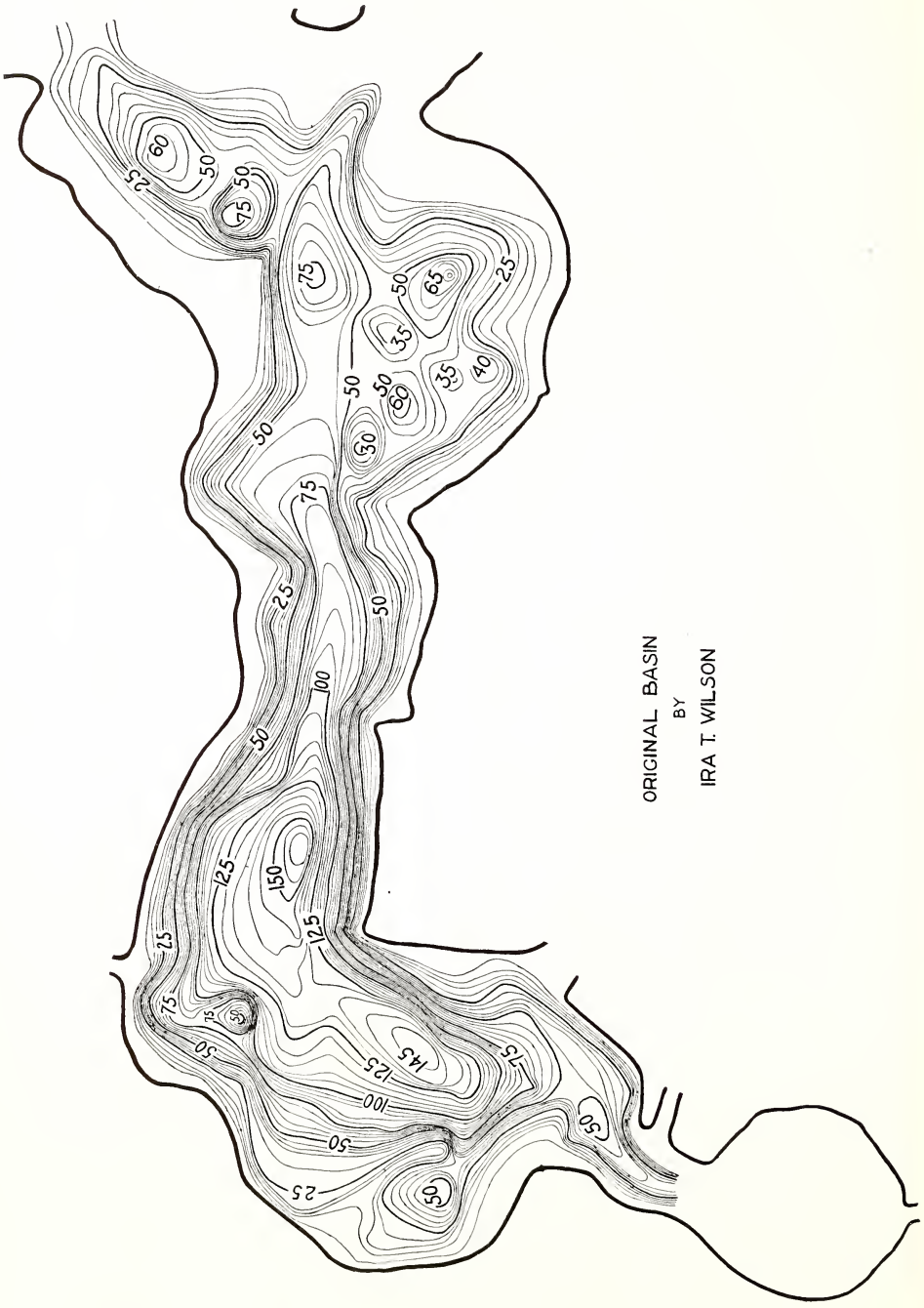
The writer's analyses of samples near shore agree with this generally but show much less carbonate (below 50%) and more silica (over 50%) in the deep water.

4. Method of Study

The method used to locate the positions of the borings (Fig. 1); the description of the boring apparatus and its use; the method of sampling, of keeping field notes, of constructing the profile diagrams and contour maps of the original bottom, and the calculation of the volume of sediment are the same as those already described in the report of the work on Winona Lake (Wilson, 1936, p. 296).

The calculations of volumes were made separately for the 3 sections (A, B, C, Fig. 3) of the lake. This was done in order to make comparisons between different parts of the basin, as section A is deep, section C shallow, and sectionl B intermediate.

In determining the hypothetical 50-percentile contours (p. 243) the following method was used: the bottom of the frustrum above and below which 50% of the sediment of the basin lies was determined by consulting tables (Tables I, II, III, and IV) which give the volume of sediment by frustra. The 50-percentile contour (i.e., the contour which, when projected vertically through the sediment, divides the sediment of the basin so that 50% lies outside and 50% inside it) lies between the contour lines of the original and present basin which fall in the base of the frustrum in question. For the purpose of study the contour


ORIGINAL BASIN
BY
IRA T. WILSON

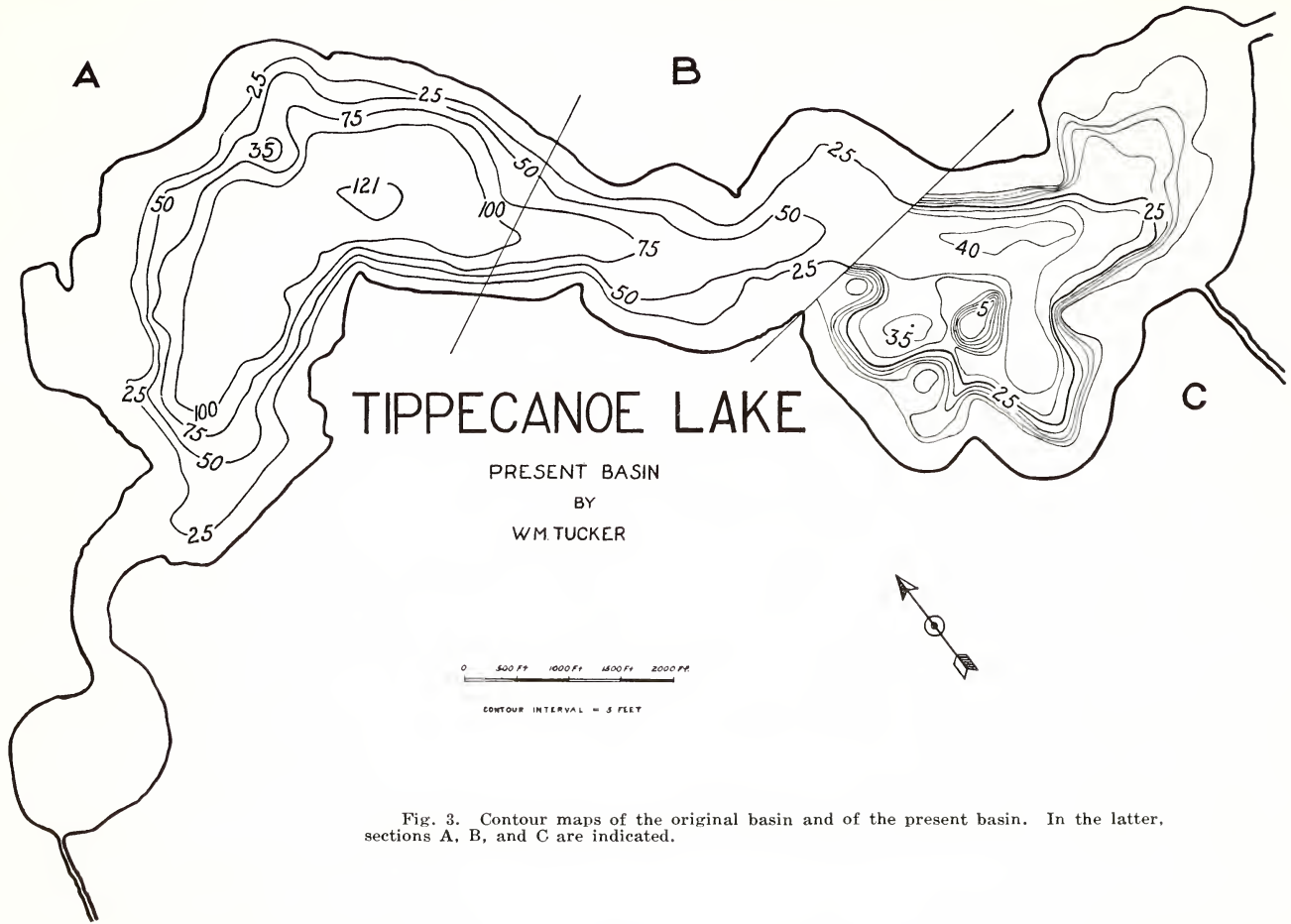


Fig. 3. Contour maps of the original basin and of the present basin. In the latter, sections A, B, and C are indicated.

TABLE I.—Volumes in cubic feet of the sediment in the frustra of Tippencanoe Lake when the lake is regarded as a cone divided into frustra by the contours of the original and present basins. The figures in the column "Volume of Sediment" represent totals of the corresponding columns in Tables II, III, and IV.

	Depth of Frustra (Feet)	Volume of Sediment	Total to Level	Percentage of Total Volume of Sediment
1.	0– 5	37,700,000	37,700,000	6.91
2.	5– 10	32,498,500	70,198,500	12.87
3.	10– 15	36,488,000	106,686,500	19.56
4.	15– 20	33,500,000	140.186,500	25.69
5.	20– 25	31,900.000	172,086,500	31.56
6.	25– 30	31,360,000	203,446,500	37.29
7.	30– 35	32,128,000	235,574,500	43.19
8.	35– 40	34,256,000	269,830,500	49.46
9.	40– 45	34,432,000	304,262,500	55.78
10.	45– 50	28,348,000	332,610,500	60.97
11.	50– 55	22,491,000	355,101,500	65.10
12.	55– 60	19,177,000	374,278,500	68.61
13.	60– 65	15,888,500	390,167,000	71.52
14.	65– 70	12,378,500	402,545,500	73.79
15.	70– 75	10,504,000	413,049,500	75.72
16.	75– 80	8,688,000	421,737,500	77.31
17.	80– 85	7,770,000	429,507,500	78.74
18.	85– 90	6,777,500	436,285,000	79.98
19.	90– 95	6,281,500	442,566,500	81.13
20.	95– 100	6,280,000	448,846,500	82.28
21.	100– 105	7,288,000	456,134,500	83.62
22.	105– 110	9,980,000	466,114,500	85.45
23.	110– 115	12,931,000	479,045,500	87.82
24.	115– 120	15,159,000	494,204,500	90.60
25.	120– 125	15,384,000	509,588,500	93.42
26.	125– 130	12,828,000	522,416,500	95.77
27.	130– 135	9,660,000	532,076,500	97.54
28.	135– 140	6,492,000	538,568,500	98.73
29.	140– 145	3,832,000	542,400,500	99.43
30.	145– 150	1,896,000	544,296,500	99.78
31.	150– 155	828,000	545,124,500	99.93
32.	155– 160	392,000	545,516,500	100.00

need be only hypothetical since the areas and volumes of sediment can be determined without locating the contours on the map. The area inside the 50-percentile contour was determined specifically by the following formula:

$$A = \frac{a_1 + a_2}{2}$$

where A is the area inside the 50-percentile contour, a_1 the area of the present basin that falls in the base of the frustrum, and a_2 the area within the contour of the original basin that falls in the base of the frustrum. The area outside the 50-percentile contour is determined by subtracting A from the total area of the original basin. The areas outside and inside the other percentile contours were determined by a similar method except that the base of the frustrum above and below which the desired percentages of the sediment lies was used as the basis of the calculations.

TABLE II.—Volumes in cubic feet of the sediment in the frustra of section A of Tippecanoe Lake when section A is regarded as a cone divided into frustra by the contours of the original and present basins.

	Depth of Frustra	Volume of Sediment	Total to Level	Percentage of Total Volume Of Sediment
1.	0– 5	11,284,000	11,284,000	4.81
2.	5– 10	10,375,500	21,659,500	9.24
3.	10– 15	14,012,000	35,671,500	15.22
4.	15– 20	12,092,000	47,763,500	20.37
5.	20– 25	11,060,000	58,823,500	25.09
6.	25– 30	9,556,000	68,379,500	29.17
7.	30– 35	8,000,000	76,379,500	32.58
8.	35– 40	7,328,000	83,707,500	35.71
9.	40– 45	6,724,000	90,431,500	38.58
10.	45– 50	5,476,000	95,907,500	40.91
11.	50– 55	4,680,000	100,587,500	42.91
12.	55– 60	4,460,000	105,047,500	44.81
13.	60– 65	4,728,000	109,775,500	46.83
14.	65– 70	4,680,000	114,455,500	48.83
15.	70– 75	4,396,000	118,851,500	50.70
16.	75– 80	4,120,000	122,971,500	52.50
17.	80– 85	4,120,000	127,091,500	54.22
18.	85– 90	4,213,500	131,305,000	56.01
19.	90– 95	4,289,500	135,594,500	57.84
20.	95– 100	4,640,000	140,234,500	59.81
21.	100– 105	6,048,000	146,282,500	62.40
22.	105– 110	9,248,000	155,530,500	66.35
23.	110– 115	12,572,000	168,102,500	71.71
24.	115– 120	15,000,000	183,102,500	78.11
25.	120– 125	15,384,000	198,486,500	84.67
26.	125– 130	12,828,000	211,314,500	90.10
27.	130– 135	9,660,000	220,974,500	94.22
28.	135– 140	6,492,000	227,466,500	97.04
29.	140– 145	3,832,000	231,298,500	98.67
30.	145– 150	1,896,000	233,194,500	99.48
31.	150– 155	828,000	234,022,500	99.83
32.	155– 160	392,000	234,414,500	100.00

5. Description and Discussion of Findings

A. Description of the Maps

Figure 1 shows a contour map of Tippecanoe Lake with the locations of the 103 borings that were made. The details of the depths of water and sediment found at any boring can be ascertained by referring to the profile diagrams (Fig. 2). The profiles are located along the lines A-A, B-B, etc., on Figure 1, and have lettering and boring numbers corresponding to them. The water level has been the point of reference in the construction of all the profile diagrams.

B. Morphometry of the Original Basin

The original bottom of the lake was very uneven due to the presence of many ridges and knobs with intervening troughs and basins (Figs. 2 and 3). In fact, 10 sub-basins, at borings 4, 6, 8, 23, 38, 55, 83, 92, 95, and 100, can be identified on the original bottom. The sub-basin

TABLE III.—Volumes in cubic feet of the sediment in the frustra of section B of Tippecanoe Lake when section B is regarded as a cone divided into frustra by the contours of the original and present basins.

	Depth of Frustra	Volume of Sediment	Total to Level	Percentage of Total Volume of Sediment
1.	0– 5	5,244,000	5,244,000	5.79
2.	5– 10	4,039,000	9,283,000	10.26
3.	10– 15	3,860,000	13,143,000	14.52
4.	15– 20	3,644,000	16,787,000	18.55
5.	20– 25	3,352,000	20,139,000	22.26
6.	25– 30	3,320,000	23,459,000	25.93
7.	30– 35	3,532,000	26,991,000	29.83
8.	35– 40	4,272,000	31,263,000	34.55
9.	40– 45	5,436,000	36,699,000	40.56
10.	45– 50	5,984,000	42,683,000	47.18
11.	50– 55	6,131,000	48,814,000	53.95
12.	55– 60	7,053,000	55,867,000	61.75
13.	60– 65	6,852,500	62,719,500	69.32
14.	65– 70	5,666,500	68,386,000	75.58
15.	70– 75	5,188,000	73,574,000	81.32
16.	75– 80	4,568,000	78,142,000	86.37
17.	80– 85	3,650,000	81,792,000	90.40
18.	85– 90	2,564,000	84,356,000	93.24
19.	90– 95	1,992,000	86,348,000	95.44
20.	95– 100	1,640,000	87,988,000	97.25
21.	100– 105	1,240,000	89,228,000	98.62
22.	105– 110	732,000	89,960,000	99.43
23.	110– 115	359,000	90,319,000	99.83
24.	115– 120	159,000	90,478,000	100.00

TABLE IV.—Volumes in cubic feet of the sediment in the frustra of section C of Tippecanoe Lake when section C is regarded as a cone divided into frustra by the contours of the original and present basins.

	Depth of Frustra	Volume of Sediment	Total to Level	Percentage of Total Volume Sediment
1.	0– 5	21,172,000	21,172,000	9.59
2.	5– 10	18,084,000	39,256,000	17.79
3.	10– 15	18,616,000	57,872,000	26.23
4.	15– 20	17,764,000	75,636,000	34.28
5.	20– 25	17,488,000	93,124,000	42.21
6.	25– 30	18,484,000	111,608,000	50.59
7.	30– 35	20,596,000	132,204,000	59.92
8.	35– 40	22,656,000	154,860,000	70.19
9.	40– 45	22,272,000	177,132,000	80.29
10.	45– 50	16,888,000	194,020,000	88.25
11.	50– 55	11,680,000	205,700,000	93.23
12.	55– 60	7,664,000	213,364,000	96.71
13.	60– 65	4,308,000	217,672,000	98.29
14.	65– 70	2,032,000	219,704,000	99.58
15.	70– 75	920,000	220,624.000	100.00

TABLE V.—Tabulation of data, some of which appear in Tables I, II, III, and IV, some are taken from the publication on Winona Lake (Wilson, 1936), but are transposed to feet, and some are new, being based on calculations the details of which are not included. The areas inside and outside the 50-percentile contours of Winona Lake and therefore, the other figures based on them, as recorded here, were calculated on the same basis as the corresponding figures for Tippecanoe Lake and differ from those previously published to a slight extent since the method used for Tippecanoe Lake (p. 000) differs slightly from that used for Winona Lake.

	Area of Original Basin (Square feet)	Area of Present Basin	Area of Original Basin Obliterated	Percentage of Basin Obliterated	Volume of the Original Basin (Cubic feet)	Volume of the Present Basin	Volume of Sediment	Percentage of Basin filled with Sediment	Area outside 50-percentile Contour
Winona	35,033,182	21,919,497	13,113,685	37.4	1,197,561,103	674,576,537	522,924,566	43.66	22,571,811
Tippecanoe as a whole	39,070,400	30,934,400	8,136,000	20.82	1,707,404,500	1,161,888,000	545,516,500	31.90	24,879,200
Tippecanoe—Sec. A	15,726,400	13,804,800	1,921,600	12.22	1,014,407,500	779,993,000	234,414,500	23.10	9,804,000
Tippecanoe—Sec. B	6,969,600	5,796,800	1,172,800	16.82	292,361,000	201,883,000	90,478,000	30.90	4,584,000
Tippecanoe—Sec. C	16,374,400	11,332,800	5,041,600	30.78	400,636,000	180,012,000	220,624,000	55.00	12,279,200

	Percentage of area of Original Basin outside 50-percentile Contour	Average depth of Sediment outside 50-percentile Contour	Area inside 50-percentile Contour	Percentage of Area inside 50-percentile Contour	Average Depth of Sediment inside 50-percentile Contour	Ratio of rate of Sediment Accum. inside and outside 50-percentile Contour	Area of Original Basin outside 20-foot Contour	Percentage of Area outside 20-foot Contour	Cu. Ft. of Total Sediment per Sq. Ft. of Area outside 20-foot Contour	Average Depth of Sediment
Winona	64.42	11.58	12,461,371	35.58	20.98	1.81	16,090,432	45.9	32.50	14.92
Tippecanoe as a whole	63.68	10.96	14,191,200	36.32	19.22	1.75	18,377,600	47.0	29.67	13.96
Tippecanoe—Sec. A	62.34	11.96	5,922,400	37.66	19.79	1.65	5,248,000	33.4	44.66	14.91
Tippecanoe—Sec. B	65.80	9.87	2,385,600	34.2	18.96	1.92	2,966,400	42.6	30.50	14.98
Tippecanoe—Sec. C	75.00	8.98	4,095,200	25.05	26.94	3.00	10,163,200	62.1	21.71	13.47
Total			12,403,200 (Sum of Parts)							

at boring 23 was 164 feet deep originally, whereas that at boring 95 was only 43 feet deep.

Four prominent knobs occurring on the original bottom are of special significance since three of them support the three "marl islands" (Figs. 1, 2, and 3). The fourth knob, "barren mound" (Figs. 1 and 2), rises 40 feet above the surrounding level. The uneven form of the original bottom with knobs, ridges, and intervening depressions, is more suggestive of rolling morainic topography than of a glacial river channel.

C. The Distribution of the Sediment

The profile diagrams (Fig. 2) show that the sediment is distributed over nearly the entire original bottom except on the barren mound (profile C-C, boring 35) and on the steep slopes on profile L-L at boring 77 and N-N at boring 86. The thickness of the sediment in different parts of the basin varies from 59 feet at boring 6 to none at boring 77; the average thickness is 13.96 feet.

In general, in the deep portions of the lake, the greatest thicknesses of sediment are in the depressions of the original bottom and the least on the ridges and mounds, as may be seen by comparing borings 4 (52 feet), 6 (59 feet), and 8 (36 feet) on profile A-A with those at borings 5 (27 feet) and 7 (11 feet). No sediment has been deposited on the knob (barren mound) on profile C-C. The average thickness of the sediment in the deep water region of the lake (within the 50-percentile contour, approximately the 65-foot contour of the present basin) is 19.22 feet (Table V).

That the sedimentary deposits on the steep slopes are much less than in deep water is shown by the fact that there is none at boring 77 (profile L-L, Fig. 2), which at that place has a slope of approximately 8°; there is also none at boring 86 on profile N-N, which has a slope of 7°. At boring 67 (profile J-J), where the slope is 6°, there are 6 feet of sediment; at boring 66, on the opposite side of the lake, there are 14 feet of sediment on a slope of 5.5°. The above figures suggest that the depth of sediment is somewhat inversely proportional to the degree of inclination of the slope, but that other factors play as important a rôle is shown by the fact that at boring 39 on profile C-C, with a slope of 4°, there are only 8 feet of sediment, and at boring 70 on profile K-K, there are 12 feet of sediment where the slope is 7°. The average thickness of sediment on the steep slopes of section A is 12.8 feet as determined by dividing the volume of sediment by the area that lies between the 40- and the 50-percentile contours. The sediment in section B between the 25- and 40-percentile contour (the steepest portion) averages 14.2 feet.

The thicknesses of sediment on the outer edges of the shelves (on the shore side of the steep "drop-offs") are greater than on the steep slopes. For example, boring 29 (profile B-B, Figs. 1 and 2) has a 28-foot deposit, and boring 61 (profile H-H) has 42 feet. The average depth of sediment between the 25- and 40-percentile contours of section A, a fairly representative zone on the outer edge of the shelf region, is 16.5 feet.

The depth of sediment in the near-shore zone (outside the 25-percentile contour) varies from zero in a few places at the shore edge (e.g., along Kalarama) to 25 feet, as at boring 30. The average depth of sediment in this zone is 7.4 feet.

A comparison of average thicknesses of sediment in the deep water, on the steep slopes (section A), on the shelf (section A), and in the shore zones (19.22, 12.8, 16.5, and 7.4 feet, respectively), together with the other data cited, shows a considerable preponderance of accumulation of sediment in the deep water and on the outer edges of the shelves.

The distribution of sediment in relation to the depth of the lake basin is indicated more satisfactorily by comparing the area of the basin inside and outside the 50-percentile line (p. 243). Table I shows, for the lake as a whole, that approximately one-half of the sediment lies above and below the base of frustrum 8, i.e., above and below a plane that cuts the lake basin into two parts horizontally at the level of the 40-foot contour lines of the original and present basins. The 50-percentile contour line, therefore, lies between the 40-foot contour lines of the original and present basins. A comparison of the figures shows that the average rate of accumulation of sediment has been 1.75 times as fast inside the 50-percentile contour as outside it.

That there has been a considerable variation in the manner of accumulation in the different parts of the basin is shown by the following ratios of the average rate inside the 50-percentile contour to that outside for each of the three sections: section A, 1.65; section B, 1.92; section C, 3.0 (Tables II-V). It is obvious that, in all parts of the lake, the rate of accumulation has been much faster within the 50-percentile contour than without. A comparison of the average depths of sediment that have accumulated in the regions inside the 50-percentile contours of the three sections (Table V) shows that the bottom in the deep water zone of section C has received more than its proportional share of the deep water accretions, and section A less. A similar study of the areas of the three sections outside the 50-percentile contours shows that the bottom outside the 50-percentile zone of section C has received less and section A more than their proportional shares of near-shore sediment. That the greater relative accumulation of sediment in the near-shore zone of section A, as compared with C, is responsible for this is emphasized by the fact that the average depth of sediment outside the 25.09-percentile contour of section A is 15.3 feet, while in section C the average depth of sediment is only 6 feet outside the 26.23-percentile contour.

D. Quantities of Sediment in Relation to Shallow Water Area

The total area of the original lake basin outside the 20-foot contour is 47% of the total area of the lake (Table V). Over 55% of this area lies in section C. The proportion of the area of each section that lies outside the 20-foot contour is as follows: section A, 33.4%; section B, 42.6%, and section C, 62.1% (Table V). The total number of cubic feet of sediment per square foot of area outside the 20-foot contour is as follows: in the lake as a whole, 29.67; in section A, 44.6; in section B, 30.4; and in section C, 21.7. These figures are of significance if it is assumed that a large proportion of the sediment is produced in the littoral zone.

Obviously, on the basis of this assumption, section C has had a much smaller portion of the sediment accumulate there than has been formed there, and this conclusion is emphasized by the fact that, although the area outside the 20-foot contour of section C comprises 55% of the total area of the lake outside the 20-foot contour, it contains only 40.44% of the total volume of sediment, whereas section A contains only 28.5% of the corresponding area but has 42.9% of the sediment.

E. Correlation of the Volumes of Sediment with the Areas of the Sections

The areas and quantities of sediment in different parts of the lake are as follows (Table V): section A, 40% of the total area of the original lake basin and 44.8% of the total volume of sediment; section B, 17.7% of the total area and 16.5% of the sediment; section C, 41.9% and 40%, respectively. The average thicknesses of sediment in the three sections are nearly equal (Table V). These data show that the quantities of sediment in the various sections are nearly proportional to the areas.

F. Volume of Sediment and Proportion of Basin Filled

The total volume of sediment in the lake (Table V) is 31.9% of the volume of the original lake basin, but the portions of the three parts of the basin that are filled differ greatly. Since section A had, in the beginning, an average depth of water of 64.5 feet, section B, 41.9 feet, and section C, 24.4 feet, it is apparent that the average original depths of the sections (A, B and C) are nearly inversely proportional to the parts that are filled (23.10%, 30.9%, and 55%, respectively).

G. Proportion of the Basin Obliterated

The emerged area of the original basin, i.e., the area between the original and present shore lines may be designated as the portion of the original basin obliterated. For the lake as a whole this is 20.82%, for section A, 12.22%, for section B, 16.82%, and for section C, 30.78% (Table V). The latter figures are fairly proportional to the percentages of the three sections that are outside the 20-foot contour of the original basin (33.4%, 42.6%, and 62.1%, respectively).

The percentage of filling of the lake as a whole and of the various sections of the lake basin is greater in every case than the percentage of obliteration of the shore zones of the same part.

H. "Marl Islands" and "Marl Ridges"

It has been noted (p. 238) that there are four knobs on the original bottom (Figs. 2 and 3). Three of these are covered with sediment which reaches to within three to five feet of the water surface; they are the "marl islands" located at borings 9, 11, and 96. The fourth knob, which is barren, is at boring 35; its peak lies 35 feet below the surface. The "marl islands" form conspicuous landmarks in the lake due to the growth of emergent vegetation on their peaks. The original knobs on which the "marl islands" at borings 9 and 11 are built rise to within 30 feet of the present water surface and the one at boring 96 to within 22 feet. They have deposited on them 27, 28, and 18 feet of sediment, respectively.

The sediment on these "marl islands" is relatively high in carbonates, most of it testing higher than 90% (that at boring 96, over 95%) as contrasted with 65% in borings 10, 54, and 55 which lie between the three islands.

The term "marl ridges" has been coined to indicate accumulations of sediment on projecting ridges of the original bottom (borings 49, 61, 64, 94, 72, 84, 87, 97, and 99) because of their high content of carbonates. For example, the carbonate in the top sample of sediment at boring 84 is 98% (the highest) while that at boring 72 (the lowest) is 82%.

On Figure 3 it can be seen that the contour lines of the present basin, at some of the "marl ridges" curving around the point more acutely than do the contour lines of the original bottom, indicate that the ridge has been building rapidly towards the center of the lake—in fact, more rapidly in most cases than in the embayments between the ridges, as shown by the greater depth of the sediment on the ridges than that at corresponding depths in the embayments. Like the "marl islands," the ridges are covered with vegetation.

I. Stratification of the Sediment in the Deltas of the Inlets

The borings made in the deltas of the two streams entering the lake (Fig. 1), namely, the James Lake Inlet (boring 3) and Grassy Creek Inlet (boring 50), and one in the delta of the mouth of a short but deep ravine along the north shore (boring 33) show alternating layers of marl and sand. This stratification is thought to be significant.

The logs of the borings in the three places mentioned above from the water surface down are as follows:

James Lake Inlet—water, 3 ft.; marl, 22 ft.; sand, 2 ft.; marl, 4 ft.; bottom (gravel).

Grassy Creek Inlet—water, 3 ft.; marl, 2 in.; peat, 2 ft.; marl, 29 ft.; sand, 4 in.; peaty marl, 4 in.; marl, 6 in.; bottom (gravel).

Ravine Delta—water, 15 ft.; marl, 8 ft.; 3 layers of sand alternating with 3 layers of marl, 9 ft.; bottom (gravel).

Alternating layers similar to these were found in the deltas of the two inlets of Winona Lake. They have not been described in detail. They resemble the alternating layers in the Ravine Delta of Tippecanoe Lake more closely than they do the creek inlet deltas.

J. The Nature of the Original Bottom of the Lake

The original bottom of the lake was found to be composed of gravel and sand and everywhere except at boring 86, which was on a steep slope and was composed of glacial drift. The terraces of the original bottom, around the edges of the lake and the ridges between depressions, have the largest particles (6 to 800 mm. in diameter), while the depressions have considerably smaller ones, the smallest, occurring in the deep depression at the west end of the lake, varying from 1 to 3 mm. The east half of the lake has, in general, larger particles than the west half.

6. Comparison of Tippecanoe and Winona Lakes.

Tippecanoe Lake is 11.5% larger in area and 42.6% in volume than Winona Lake. Its greater excess in volume as compared with area is

due to its greater average original depth (43.7 ft. as compared with 34.2 ft.). The greatest absolute depth of the original basin of Winona Lake was 128 feet, and of Tippecanoe, 164 feet (boring 23); the greatest present depths are 80 and 123 feet, respectively.

The area outside the 20-foot contour of the original basins is a fair measure of what has formed the littoral regions of the lakes during their past histories. Winona Lake has had 45.9% of its area outside the 20-foot contour, while Tippecanoe has had 47.0% outside (Table V).

Winona Lake has 37.4% of the original basin around the edges raised above the present water level, whereas Tippecanoe has only 20.8% obliterated. These figures are significant since, as shown in the preceding paragraph, the percentages of original littoral zones in the two basins are very nearly the same.

The absolute volume of sediment in Tippecanoe Lake is slightly more than that in Winona (Table V). These quantities, however, are fairly proportional to the areas of the original basins of the two lakes as shown by the nearly equal average depths of sediment in the two basins.

The proportion of the original basin of Winona Lake filled with sediment is 43.66% (Table V) as contrasted with 31.90% for Tippecanoe Lake. The inverse correlation existing between the proportions of the two basins that are filled and their respective average original depths (34.20 and 43.77 feet) is the same as for sections of Tippecanoe Lake (p. 243).

The percentage of areas of Winona Lake and Tippecanoe Lake that are outside the 50-percentile contours are 64.42% and 63.68%, respectively. The average thicknesses of sediment of the two lakes in these regions are 11.58 and 10.96 feet, respectively, a slight advantage in favor of Winona Lake. The percentages of areas of the two lakes that are inside the 50-percentile contours are 35.58 and 36.32, respectively, and the average depths of sediment are 20.98 and 19.22 feet; this is also a slight advantage in favor of Winona.

The ratio of the sediment that has accumulated inside to that which has accumulated outside the 50-percentile contour for Winona Lake is 1.81 and for Tippecanoe 1.75 (Table V). This is a slight advantage in favor of Winona Lake.

The 50-percentile contour occurs between the 33-foot contours of the present and original basins in Winona Lake and between the 40-foot contours in Tippecanoe. The number of cubic feet of the total sediment in the lakes per square foot of area outside the 20-foot contour are, respectively, 32.50 and 29.67, showing a considerable advantage in favor of Winona Lake and constituting a fact of some significance if a very large proportion of the sediment of the lakes has originated in the littoral zones.

7. Discussion and Conclusions

The fact that the lake basin is at present and, for some time past, has been almost completely sealed from the underlying original bottom precludes the possibility that much interchange of lake water can take or has taken place with ground water. This would imply that most of

the chemicals in solution in the lake (particularly calcium carbonate) that are precipitated out to form sediment are derived, at the present time, from the surrounding terrain by surface drainage. The abrasion of the gravel, sand, and clay washed into the littoral zone of the lake is probably the source of most of the silicates and aluminates found in large quantities in the sediment, especially in the deep water zone.

The varying thicknesses of sediment found in different parts of the basin are indicative of dynamic factors at work in its distribution. That the deep-water zones have been the best depositories of sediment is, no doubt, due to the fact that when sediment settled there it remained. The outer edges of the shelves have more sediment on them than occurs on the steep slopes or in the near-shore region because they are deep enough to be below the zone of wave erosion and flat enough to retain sediment once it has fallen on them. The near-shore zone has very little sediment because much that settles there is eroded away. If that does not happen, the zone is soon filled and emerges from the water and, of course, cannot be a further depository of sediment.

That the depressions in the deep-water zone of the lake accumulated sediment much faster than did the contiguous ridges is probably due to the slower currents there when there was general circulation of the lake water. This process probably continued until the depressions were filled to the level of the ridges. After the lake bottom became more regular and smooth, deposition of the sediment was undoubtedly fairly uniform over the bottom in the deep water because the current was more regular. The fact that there is no sediment at all on the "barren mound," even now, and that the sediment around its base has, as yet, not nearly reached its level (40 feet below) is further evidence tending to substantiate this statement.

The following facts and probabilities must be considered in any theory attempting to explain the dynamic factors involved in the distribution of sediment in Tippecanoe Lake.

1. The volume of sediment in each section bears the same relation to the total volume of sediment in the lake as the area of each section bears to the total area.

2. The zone inside the 50-percentile contour in section C has accumulated more sediment, and the zone outside the 50-percentile contour less, than expected on the basis of equal rate of accumulation per square foot of area, but just the reverse relationship obtains within section A.

3. It is likely that sediment is formed equally in all parts of the deep-water zones of the lake.

4. Probably most of the sediment is produced in the shallow-water region of the lake.

5. More than 55% of the area outside the 20-foot contour of the original basin lies in section C, but section C contains only about 40% of the sediment, while section A has only 28.5% of its area outside the 20-foot contour and contains 42.9% of the sediment.

If the above assumptions are valid, then the facts cited can be explained by assuming that most of the sediment in the lake has been produced in the zone outside the 20-foot contour of section C, but that a large part of it has been dislodged and abraded by the vigorous wave

action at that end of the lake, and, subsequently evenly distributed over the whole lake by currents, has settled out fairly uniformly, especially in the deep-water region. Conversely, section A at the windward end of the lake has had relatively little of its sediment in the shallow-water zone dislodged.

This theory accounts for the fact that the sediment is distributed in proportion to the areas of the three sections, i.e., is generally distributed. At the same time it accounts for the higher ratio of sediment in the zone outside the 50-percentile contour in section A and the lower ratio than expected in the corresponding zone of section C. To account for the unexpected excess of sediment within the 50-percentile contour of section C, it is only necessary to assume that not quite all the dislodged sediment from the littoral zone of section C is distributed evenly, but that slightly more of it settles out in the deep water of that section since the deep-water zone of section C is closer to the source of most of the sediment, namely, the broad littoral region of section C, than is the deep-water zone of either of the other sections. The very high ratio of shallow- to deep-water regions in section C (2.5) as compared to the same ratio in section A (.9) lends credence to this assumption.

An alternative explanation to account for the fact that section A, outside the 50-percentile contour, has received more sediment than section C is that this zone in section A has more of its area outside the 50-percentile region in deep water than is the case in section C, and, therefore, it has more area in this zone that is a good depository for sediment than is the case in section C, which is broad and flat, and, therefore, has more of its area subjected to wave attack. That this discrepancy can be accounted for by possible accretions from the two inlets is rendered unlikely by the fact that chemical analyses of the sediments in the different sections show the sediment in the deep-water zone of section C to be higher in carbonates (80-90%) than the corresponding sediment in section A (50-60%). If the sediment in section C had been deposited by the entering streams, it would have been largely silica and organic matter. Furthermore, if stream deposition were the cause of the excess, the total quantity of sediment in section C should be more than expected on the basis of equal distribution by sections. This is the antithesis of the case; it is deep-water zone of section A that has more material than expected, and section C less (page 243).

It is likely, on the basis of this theory, that it is a mere coincidence that the amounts of sediment in the three sections are nearly equal per square foot of surface, because, if the lake were turned end for end so that the large littoral zone of section C were at the west or windward end instead of the east or lee end, it is likely that section A would not have received so much sediment dislodged from the littoral zone of section C because, in that case, not so much sediment would have been dislodged from section C. It would be expected that by the present time section C would be entirely filled and section A would have only a fraction of the sediment in the deep-water zone that it does have under the existing conditions.

Since the percentages (23.1%, 30.9%, and 55%) of the three parts of the original basin (A, B, and C, respectively) that are filled are in-

versely proportional to the average original depths of the basin (64.5, 41.9, 24.4 feet, respectively), and since the average thicknesses of sediment in the three parts (14.91, 12.98, and 13.47 ft. respectively) are nearly equal (showing an average equal sedimentation per square foot of the area), the conclusion is inevitable that the proportions of the basins of the various sections of this lake that are filled are dependent on the original depths of the basins; the greater the original depth, the lower proportion of the basin that is filled.

The fact that the rate of obliteration of the basins (emergence of the shallow near shore zone) is fairly proportional to the percentage of the area of the various sections of the basins that lay outside the 20-foot contour can be explained on the basis that the waves break and expend their energy farther out in the lake in a broad near-shore zone than in a narrow one, and, therefore, the accumulations of sediment along the edge of the shore in the former case are less likely to be dislodged.

With the persistence of the filling of the middle of the various basins more rapidly than the areas along shore are being obliterated and the filling on the outer edges of shelves (outside the "drop off") faster than on steep slopes, it can be predicted that a condition will be reached eventually where the lake basin will have the form of a broad flat emerged zone with a steep drop-off to a body of shallow water of uniform depth in the former deepest part of the basin. From this point on it can be predicted that the rate of filling in the center will be less rapid than the obliteration of the area around the edges, because, as the lake becomes older, the rate of filling in the center will decelerate, due to less effective abrasion and circulation. This would be expected since, as the lake grows smaller, the waves become smaller. Also, with less wave action, accumulation at the edges would be expected to accelerate. The final shallow remnant of the lake would be expected to be obliterated by the typical encroaching, mat-forming association of plants characteristic of bogs.

The presence of alternating layers of sand and marl in the lower reaches of sediment in every inlet studied in the two lakes certainly indicates some general change in conditions. The most obvious suggestion is a change in climate involving considerable fluctuations in rainfall. During wet periods, with the attendant influx of swift-flowing water, it can be supposed that more sand was carried by the streams and carried farther into the lake than in dry periods. The resultant deposition of sand overwhelmed the slow deposition of the more characteristic lake sediment. During relatively dry climatic conditions the streams would be sluggish, and the amount of sand carried would be small, and it would not be carried so far into the lake; therefore, the more characteristic lake sediments would be dominant in the delta regions. The data are too fragmentary to permit any attempt to correlate the strata with definite post glacial climatic periods as has been done with pollen profiles. Further and more extensive and careful work is planned in the near future on this aspect of the sedimentation problem.

Since all the "marl islands" are built on knobs which rise to within 30 feet of the water surface, whereas the "barren knob" rises only to within 35 feet of the surface, the explanation offered for the occurrence

of the two similar "marl islands" in Winona Lake seems applicable here, namely, that the knobs on which they occur were close enough to the surface to permit the establishment of vegetation, which caused the precipitation of the carbonates when they utilized the half-bound carbon dioxide in the calcium bicarbonate in their photosynthetic activity. The carbonates settled to the bottom, and they remained there because the building island was isolated from shore and, therefore, not affected by waves of translation until near enough to the surface to cause waves to break. After this point was reached, they could not build higher because their accumulations were eroded and carried away as fast as formed. The fact that the "barren knob," with its top within 35 feet of the water surface, did not support vegetation indicates that, in an early period of the lake, 30-35 feet must have been the limit of effective light penetration for plant growth and thus the critical depth so far as "marl island" formation was concerned.

This theory is in marked contrast with one made by Blatchley and Ashley (1900, p. 50) to account for "marl islands." They said, ". . . they are probably above and surrounding the orifice of a former large subaqueous spring which bubbled up from the bottom of the lake." The writer has found in the five "marl islands" studied no evidence justifying the notion that springs existed on "marl islands," or anywhere else in the bottom of the lake, for that matter. As was pointed out (p. 248), the sediment seems to have sealed off the original bottom almost completely from the present basin.

An explanation similar to that made for the "marl islands" is adaptable to the "marl ridges." They were ridges on the original bottom extending out from shore, too deep to be affected by waves but shallow enough for the growth of vegetation. The accumulations of sediment on the ridges has made them more prominent features (both vertically and horizontally) of the present bottom than they were of the original bottom; consequently there exists the peculiar phenomenon in Tippecanoe Lake of the lake shore becoming more irregular at the present time than it was in the earlier stages. In this particular lake it can be predicted that, if this process continues, the lake will eventually be cut into separate parts by further extension of the opposite points along the line K-K (Fig. 1) and perhaps at other points as well.

The gravel particles of the original bottom in the depressions are too large (1 to 3 mm.) for characteristic lake currents to have carried them from the terraces and ridges to their present location. It would be necessary to assume that the assortment took place when very large volumes of water were flowing through the lake. It is quite possible that such was the case in the early history of the lake, the source of water being the melting ice of the receding glacier. The size of the valley of the Tippecanoe River probably supports such a thesis.

The slightly larger average depth of sediment in Winona Lake than in Tippecanoe Lake (14.92 and 13.96 feet, respectively) probably falls within the range of error in calculating areas and volumes; it appears, therefore, that the productivity of sediment in the two lakes has been remarkably near the same per square foot of area on the average. To what extent this kind of comparison in quantity of sediment could be

utilized as a measure of the relative biological productivity of these two lakes will have to await chemical analyses of the sediment and the determination of the relative proportions of the sediment that have arisen from biological and physical activity.

The proportions of the areas outside the 20-foot contour of the two lakes have been so nearly alike (Winona 45.9% and Tippecanoe 47.0%) that, taken alone, they do not justify any dogmatic inferences as to the relative proportions of sediment that have originated in the littoral and the pelagic zones. Assuming, however, that the deep-water areas have, per square foot, been equally productive of sediment, the fact that Winona Lake, as compared with Tippecanoe, has a greater quantity of the total sediment per square foot of littoral area (32.5 and 29.67 feet, respectively) warrants the suggestion that the Winona Lake littoral has been the more productive of sediment.

The fact that Tippecanoe Lake has a less obliterated surface zone (20.8%) than Winona Lake (37.4%), but had about the same proportion of area outside the 20-foot contour originally (47.0% and 45.9%, respectively), can be explained satisfactorily on the assumption that Tippecanoe Lake, being larger, especially longer (2.3 miles), than Winona Lake (1.7 miles) has had waves with greater energies, which have more effectively eroded the sediment lodged in the littoral zone and transported it to the deeper water.

Since the portions of the original basins filled with sediment (43.66% in Winona and 31.9% in Tippecanoe) are inversely proportional to the average original depths of the basins (34.20 and 43.77 feet, respectively), and since a similar inverse proportion holds for each of the three sections (A, B, and C) of Tippecanoe Lake, it is certain that factors other than depth are principally responsible for the quantity of sediment produced in a lake. It has been pointed out already that the quantities of sediment are nearly proportional to the areas of the lakes; thus it is obvious that, other things being equal, which is a condition almost attained in the two lakes under consideration, the relative quantities of sediment produced in these lakes are fairly proportional to the amounts of sunlight falling on them.

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A Method for the Preparation of Dry Skeletal Material

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The preparation of transparent specimens by the Spalteholz method depends upon the fact that flesh can be decolorized with 1% potassium hydroxide. While following this method the author allowed a specimen to clear for too long a time and thus discovered that the hydroxide solution will destroy flesh, ligaments, and bones, in the order named. But, if maceration is stopped at the right time, ligaments and bones can be perfectly preserved. Detailed methods for preparing skeletal material with hydroxide are given below.

Skulls and Disarticulated Bones. Short method.—Skin and clean the animal. Fix in 95% alcohol for at least 24 hours. Place in 1% potassium hydroxide at 40° C. until bones are cleaned and disarticulated, changing fluid once or twice. Remove, wash, and dry. Rat skeleton requires 3 days. **Long method.**—Proceed as above, but carry on the entire process at room temperature. A safer method, but it requires several weeks.

Ligamentous Skeletons.—Skin animal except for nose and feet. Remove viscera posterior to the diaphragm. Arrange in natural position and fix in 95% alcohol for at least 24 hours. Soak in 1% potassium hydroxide at room temperature until the flesh becomes colorless, changing fluids two or three times. Place in fresh solution and dissolve flesh at 40° C. Remove when the first signs of disarticulation appear (lower jaw usually falls off first). Wash in a fine jet of water, mount, and dry. Rat skeleton requires two weeks or more for clearing, three hours for dissolving flesh.

Cautions.—Hydroxide solution must be thoroughly mixed, as the hydroxide sinks and will act unevenly if concentrated in the bottom of the dish. Do not cut away flesh, as this exposes bones to the action of the hydroxide. Do not let cleaned bones remain in the hydroxide, as they will eventually dissolve. Keep vessel covered, so that the solution is not concentrated by evaporation. On the whole, the slower the action the better the preparation. The highest safe temperature for clearing is about 25° C. The above directions apply specifically to the skeletons of small mammals.

The superiority of the hydroxide method over the older ones lies in the fact that the macerating agent is allowed to penetrate all parts of the muscles so thoroughly that its action is almost uniform. The 95% alcohol dehydrates the specimen and thus facilitates penetration by the hydroxide.

Attempts to speed up the clearing process have met with little success. Increasing the strength of the hydroxide (to 3%) produces a fairly clean skeleton but swells the periosteum to a thick jelly, weakens the ligaments, and weakens lightly ossified bones such as the

ribs. Increasing the temperature during clearing (as in the short method given above) will produce maceration in a short time, but the limb bones fall apart before the thicker muscles are dissolved. The results indicate that heat is injurious to any but the strongest bones.

Formalin specimens may be used, but clearing and maceration are extremely slow. The entire process may be carried on at 40° C. with such specimens.

The hydroxide method has so far been applied chiefly to small mammals. Preliminary experiments with amphibia indicate that the 1% solution of hydroxide is too strong.

Prolonged action of the hydroxide not only decolorizes the bones but also converts all fat to soap and leaves them perfectly clean. There is no necessity to brush the skeleton or to use bleaching agents, either of which processes may damage the skeleton. There are no unpleasant odors of decomposition during clearing or maceration following fixation in alcohol.

The ligamentous skeletons are wonderfully strong and elastic when wet and, in small mammals at least, require practically no support when mounted. Every bone except the hyoid remains articulated. Even the penial bone of the male rat is preserved.

The method is one which involves a very small amount of trouble. Excluding the labor of mounting, a completely cleaned rat skeleton may be prepared with approximately 1½ hours' actual attention. Furthermore, even totally inexperienced workers are able to produce Grade A preparations on the first trial.

Heldout, a Recessive Wing Mutation in Drosophila Melanogaster

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During July 1935, a few flies holding their wings at right angles to their bodies were discovered in a stock bottle of *Drosophila melanogaster*. These were mated *inter se* and a pure strain was obtained. While the wings vary in extension from 45° to 90° from the body axis, they apparently never show the parallel or folded-together position of the wild-type fly. Because of this characteristic position of the wings, the mutation was named straight, symbol *str*, but it was renamed heldout, symbol *ho*, upon the suggestion of Dr. Bridges of the Carnegie Institution of Washington, to whom we are indebted for advice throughout the course of these experiments.

Allelomorphic tests were made with other wing characters with negative results. The results showed in addition that heldout is recessive and not sex-linked.

Chromosome Carrying Heldout

To determine whether the gene for heldout is in the third chromosome, a heldout female was crossed to a sepia male and three F_2 pair cultures raised (Table I).

TABLE I.—F_2 Distribution (P_1, heldout ♀ x sepia ♂; F_1 wild-type ♀ x F_1 wild-type ♂).

May 23, 1936	wild-type	heldout	sepia	heldout sepia
Total.....	187	53	34	18

The appearance of double recessives showed that heldout is not in the third chromosome. The failure of the phenotypes to appear in a ratio closer to the expected 9:3:3:1 was undoubtedly caused by not counting the offspring for more than two days because of confirmatory evidence from the simultaneous experiment described below.

A heldout female was crossed to a black male to find out if heldout is in the second chromosome. Three F_2 pair cultures were raised (Table II).

TABLE II.—F_2 Distribution (P_1, heldout ♀ x black ♂; F_1 wild-type ♀ x F_1 wild-type ♂).

May 23, 1936	wild-type	heldout	black	heldout black
Total.....	128	57	51	0

The results plainly show a 2:1:1:0 ratio, proving that heldout is in the second chromosome.

Preliminary Localization of Heldout

A heldout male was mated to a brown female, and several brown and heldout flies from the F_2 were mated *inter se*. From the F_3, several heldout brown individuals were obtained, from which a stock was established. The ease with which the heldout brown combination was obtained gave preliminary indication of a high rate of crossing-over between heldout and brown. Several heldout brown males and females were mated to wild and heterozygous females from the F_1 backcrossed to heldout brown males (Table III).

TABLE III.—Result of Backcross (P_1, heldout brown x wild; F_1 wild-type ♀ x heldout brown ♂).

Jan. 21, 1937	heldout brown	wild-type	heldout	brown	N	Recombinations (R)
Total.....	464	549	492	466	1971	48.6%

The very high percentage of recombination indicated that the locus of heldout is very distant from that of brown, which is at 104.5.

In the same way that the heldout brown stock was obtained, a stock containing heldout black and purple was made up. Males from the heldout black purple stock were mated to wild females, and heterozygous females from the F_1 were backcrossed to heldout black purple males (Table IV).

TABLE IV.—Results of Backcross (Feb. 18, 1937) (P_1, heldout black purple ♂ x wild ♀; F_1 wild-type ♀ x heldout black purple ♂).

Parental Combinations		Recombinations						N	R	R
ho b pr		ho + +		ho b +		ho + pr			ho-b	b-pr
+ + +		+ b pr		+ + pr		+ b +				
heldout black porple	wild-type	heldout	black purple	heldout black	purple	heldout purple	black			
500	591	222	199	13	11	3	0	1539	27.6%	1.8%

The fairly large amount of recombination for heldout and black showed that the locus of heldout is probably more than 30 units to the left of the locus of black, which is at 48.5.

From the above experiment it seemed probable that the locus lies near 13, and, to determine whether it lies to the left or right of this locus, a cross was made with dumpy clot (*dp*, 13.0; *cl*, 16.5). A heldout male was mated to a dumpy clot female; all the F_1 were wild-type. Heterozygous females were backcrossed to dumpy clot males. Crossovers from the F_2, easily identified since they were dumpy only or clot

only, were mated to heldout females. There were three possibilities: if heldout should lie to the left of clot (*ho + +/+ dp cl*), then the not-dumpy clot cross-overs would also carry heldout while the dumpy not-clots would not; if heldout should lie to the right of dumpy (*dp cl +/+ + ho*), the dumpy not-clot cross-overs would carry heldout, whereas the not-dumpy clots would not; if, however, both kinds of cross-overs should carry heldout, then heldout would lie both to the right of dumpy and to the left of clot, that is, between them (*dp + cl/+ ho +*).

When males of the two kinds, dumpy and clot, were mated separately to heldout females, the clot flies produced both wild and heldout, whereas the dumpy produced only wild, showing that the locus of heldout actually lies to the left of clot.

A stock containing the recessives heldout and clot was obtained from the last experiment, and females were mated to males with the genotype Mz/Inversion (Minute-z, 13.0±). F_1 females showing Minute were crossed to heldout clot males. The totals for this three point cross were as follows:

TABLE V.—Results of Backcross (May 30, 1937) (P_1, ho cl ♀ x Mz/Inversion ♂; F_1 Mz ♀ x ho cl ♂).

Parental Combinations			Recombinations						N	R.	R.
ho	+	cl	ho	Mz	+	ho	+	+		ho-Mz	Mz-cl
+	Mz	+	+	+	cl	+	Mz	cl			
heldout clot		Minute-z	heldout Minute-z		clot	heldout		Minute-z clot			
638		661	62		158	16		23	1558	14.1%	2.5%

From the above table it is evident that the locus of heldout is considerably to the left of Minute-z. A cross was made therefore with Star (*S*, 1.3), by mating Star/Curly females to heldout males, and crossing the F_1 Star females to heldout males.

TABLE VI.—Results of Backcross (P_1, S/Cy ♀ x ho ♂; F_1 S ♀ x ho ♂).

July 2, 1937	Star	heldout	Star heldout	wild-type	N	R.
Totals.....	1786	1787	49	52	3674	2.7%

The locus is therefore about 2.7 units from Star. To find out whether it is to the right or left of Star, females having the genotype *S ho +/ + + Mz* or else *ho S +/ + + Mz* were mated to heldout males. The cross-overs examined included Star Minute flies and heldout flies, showing that heldout lies to the right of Star. Therefore the locus was placed at approximately 4.

Final Localization of Heldout

The final step in the localization of heldout was a three-point backcross involving aristaless (*al*, 0.0) Star and heldout (*al S ho*/+ + +). To get the *al S ho* combination, *al S/Pm, ds*[33k] males were mated to heldout females and F_1 Star females were backcrossed to heldout males (Table VII).

TABLE VII.—Results of Backcross (P_1, al S/Pm, ds [33k] ♂♂ x ho ♀♀; F_1 al S +/+ + ho ♀ x ho ♂).

Nov. 2, 1937	Star	heldout	Star heldout	wild-type	N	R. S-ho
Totals	520	493	13	13	1039	2.5%

Cross-overs showing both Star and heldout were then mated to Star/Curly and the Star Curly offspring inbred to give a balanced lethal stock with the genotype *al S ho/Cy*. Similar cross-overs were mated to wild to get the heterozygous females necessary for the three-point experiment.

In order to obtain an aristaless heldout stock, an aristaless male was mated to a *S ho/Cy* female (Table VIII). F_1 Star females then were mated, not to heldout, as would ordinarily be done, but to *S ho/Cy* males. The Curly offspring were discarded without counting, and advantage was taken of the lethality of homozygous Star in eliminating half of the remaining offspring. This type of "backcross" is advantageous over the ordinary backcross in the following respects: first, there are only two (non-Curly) phenotypes to be counted instead of the usual four; second, all the *S ho* flies carry the desired *al ho* genotype; and third, all the cross-overs can be identified quite easily. The objections to this procedure are: first, the number of flies counted is one-fourth normal; and second, there is no balancing of differential mortality. In this particular case these objections do not hold because the purpose of the experiment was to obtain an *al ho* strain, counts for the percentage of recombinations being incidental, and both *ho* and *S* are practically as viable as wild.

TABLE VIII.—Results of "Backcross" (Sept. 29, 1937) (P_1, S ho/Cy ♀ x al ♂; F_1 S ♀ x S ho/Cy ♂—Cy flies discarded).

Zygotes	al + + / + S ho	+ S ho / + S ho	al + ho / + S ho	+ S + / + S ho	N	R. S-ho
Phenotypes	Star	hom. Star (dies)	Star heldout	hom. Star (dies)		
Total	375	0	7	0	382	1.8%

Females having the genotype *al S ho*/+ + + obtained from mating the cross-overs from Table VII were backcrossed to *al ho* males procured by selfing the cross-overs from Table VIII. The results of this cross (Table IX) confirm previous localizations of heldout.

TABLE IX.—Results of Backcross (Nov. 26, 1937) (al S ho/+ + + ♀ x al ho ♂).

Parental Combinations			Recombinations				N	R. al-S	R. S-ho
al	S	ho	al	+	+	al	S	+				
+	+	+	+	S	ho	+	+	ho				
aristaless Star heldout		wild-type	aristaless		Star heldout	aristaless Star		heldout				
3593		3821	16		17	123		94	7664	0.4%	2.8%

Although the 0.4% of crossing-over between aristaless and Star is much smaller than the generally accepted value of 1.3%, the agreement of the percentage between Star and heldout with that obtained in other experiments indicated that the experiment is reliable.

A total of 12,759 flies were counted in experiments giving 351 cross-overs. This is a cross-over percentage of 2.7, which, when added to the locus of Star, 1.3, places the locus of heldout at 4.0 in the second chromosome.

The accurate localization of heldout at 4.0, its high viability, strategic position, and easily distinguishable characteristic make it a mutant of the first rank (RK1). Its characteristics are summarized in the manner customarily used in describing Drosophila mutants, as follows: *ho*—heldout; Novitski, 35g (2-4.0) Spontaneous. Wings extended at 45° to 90° from body axis. RK1.

References

For an account of the previously known mutants in this region, as well as the various mutants used in the course of this problem, consult the following:

1. Stern, C. and C. B. Bridges, 1926. The mutants at the extreme left end of the second chromosome of *Drosophila melanogaster* Genetics **11**:503-530.

2. Drosophila Information Service, 1935. Carnegie Institution of Washington, Department of Genetics, Cold Spring Harbor, N. Y.

New Mexican Gall Wasps (Hymenoptera, Cynipidae). IV

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An adequate analysis of the Mexican cynipid fauna cannot be made until the species of that fauna have been named and described, and their relationships carefully considered. The present series of papers describing that fauna should provide the materials from which we may ultimately build faunistic analyses and some story of the processes of evolution.

The 16 new species described in the present paper include representatives of the genera *Cynips, Disholcaspis,* and *Neuroterus.* A new genus, *Conobius,* is described with one new species from Mexico.

In *Cynips,* there are 6 species to be added to the 170 included in our previous publications on that group (Kinsey 1930 and 1936). Five of these *Cynips* species are from the northeastern portion of Mexico; one is from the area southeast of Mexico City. Five of the species are from complexes *(arida, nubila,* and *plumbea)* well represented in our previous treatment of the Mexican groups; but one species, *C. (mellea) sagata,* is from a complex previously known only from the southeastern quarter of the United States.

The three new species of *Disholcaspis* belong to the *cinerosa, fungiformis,* and *mexicana* complexes. The first and last have previously had lone Mexican representatives described; the *fungiformis* complex has been known heretofore only from Central Texas.

The six species of *Neuroterus* represent the first members of that genus to be recorded from Mexico. The new species belong to four different complexes.

Faunistically, these Mexican species line up as follows: One species *(Conobius strues)* from the Western Sierra has its described relatives in our Southwest; two of the Western Sierran species *Neuroterus reconditus* and *N. tumba,* belong to groups which are known from all parts of the United States. Among the Eastern Sierran species there are five *(Cynips conspecta, C. rubella, C. lanaris, C. molucrum,* and *C. torosa)* which have their chief affinities in the Western Sierra and in our Southwest. More notable among these Eastern Sierran species, there are three *(Cynips sagata, Disholcaspis insulana,* and *D. pallens)* whose relatives occur chiefly in the southeastern quarter of the United States. See *D. (cinerosa) pallens* for a discussion of the present-day contacts between the northeastern Mexican and Eastern Texan oak floras and cynipid faunas. Finally, there are four species of *Neuroterus (N. junctor, N. visibilis, N. volutans,* and *N. vulpinus)* which have both Eastern American and Californian affinities, although there are no known relatives in the Rocky Mountain area in the United States.

This is our fifth publication on Mexican Cynipidae, and the fourth under the present title. Previous papers have appeared in the INDIANA UNIVERSITY SCIENCE SERIES (No. 4, 1936), and in volumes 7 and 8 of the REVISTA DE ENTOMOLOGIA (1937 and 1938). The material herein

[1] Contribution from the Department of Zoölogy, Indiana University, No. 272 (Entomological Series No. 22).

described comes from collections which we made in 1931-32, and in 1935-36, on Mexican expeditions supported in part by Indiana University and the National Research Council (U.S.A.). Further acknowledgment should be made for courtesies extended by numerous Mexican government officials. The National Youth Administration in Indiana has, for several years, provided part of the technical assistance employed in preparing this insect and gall material for study.

Conobius, new genus

agamic forms

FEMALE.—Head fully as wide as thorax, punctate and hairy, face broad and flat, cheeks well protruded beyond eyes, without a malar furrow; antennae with 13 (or obscurely 14) segments. Mesonotum punctate and coriaceous to finely rugose, sparsely hairy, scutellum more coarsely rugose; parapsidal grooves continuous, fine for whole length, or slightly wider posteriorly, well separated at scutellum; anterior parallel lines fine, slightly raised, not prominent; lateral lines poorly indicated; median groove absent or indicated right at scutellum; scutellum depressed anteriorly, with two rather broad, rounded, usually smooth, but shallow and poorly separated foveae; mesopleuron rugose to striate on ventral half, smoother on dorsal half. Abdomen longer than high, slender, not produced dorsally or ventrally, second segment covering about one-half of whole, entirely smooth and naked except for a sparse patch of hairs latero-basally, or finely punctate and hairy on lateral edges of segments 3 to 5; hypopygial spine fine, slender, about 0.08 of body in length, hairy for whole length of ventral edge. Legs punctate and hairy, tarsal claw of moderate weight only, distinctly toothed. Wing tinged smoky yellow, of fair length, slender, with wing-body ratio averaging about 1.30; front and hind margins non-ciliate, outer margin only very short-ciliate; whole hind margin of hind wing long-ciliate; subcosta, basalis, and radius heavier than other veins which are usually fine and light in color; usual break in subcosta bridged by one edge of vein; radial cell slightly shortened, open; first abscissa of radius sharply angulate, without a projection or with a short projection at tip of angle, hardly infuscated; second abscissa of radius slightly curved; areolet small to moderate in size; cubitus continuous or discontinuous; length 2.2 to 3.2 mm.

Fig. 1. Conobius strues, new species
From Western Mexican Sierra, state of Chihuahua. Paratype galls, natural size.

GALL.—Woody, seed-like cells densely clustered on stems, the clusters resembling small nubbins of dent corn. Each cell monothalamous, roughly conical, sharply pointed at place of attachment, expanding into a broadened, distinctly flattened top, the top centrally tipped with a small scar, the individual galls mis-shapened, often flattened on the sides because of the pressure within the cluster of galls; each cell covered with a thin, hard-papery epidermis which usually shrivels or becomes fluted, and sometimes flakes off in dried galls. Internally each gall compact, woody, with a spherical larval cell centrally placed in the expanded, upper end of the galls, the cell relatively small, without a separate lining. Adventitious bud galls, occurring in dense clusters of up to 30 galls, on the sides of the twigs of the hosts.

HOSTS.—White oaks, probably including several of the species found in the area involved.

RANGE.—Known from New Mexico and Arizona to Jalisco. At least throughout the southern Rocky Mountain area of the United States and the Western Sierra of Mexico.

GENOTYPE.—*Conobius strues* Kinsey (described below).

The most distinctive characters of this genus are the broad and flattened face with the cheeks protruding well beyond the eyes, the lack of a malar groove, the 13- (or obscurely 14-) segmented antennae, the continuous parapsidal grooves, two distinct foveae, slender but not long hypopygial spine with its row of hairs on the ventral margin, the toothed tarsal claw, wings which are non-ciliate on all but the outer margin, and monothalamous, seed-like galls which are clustered like nubbins of corn on the sides of the twigs of the oaks involved. Bassett's *spicatus*, from the Southwestern United States, and the Mexican species *strues*, described below, are typical of the genus. There are several other described species from the United States which are related, but the extent of the group will have to be worked out when a monographic revision of the whole genus can be made. Bassett's species *spicatus* is re-described here from type material, in order to give a better basis for comparison of the new Mexican species.

Conobius (spicatus) spicatus (Bassett)

agamic form

Loxaulus spicatus Bassett, 1900, Trans. Amer. Ent. Soc. 26:329. Dalla Torre and Kieffer, 1902, Gen. Ins. Hymen. Cynip.: 54. Dalla Torre and Kieffer, 1910, Das Tierreich, 24:388, 802. Felt, 1918, N. Y. Mus. Bull. 200:71. Cresson, 1923, Trans. Amer. Ent. Soc. 48:202. Weld, 1926, Proc. U. S. Nat. Mus. 68(10):45.

Loxaulus spicata Thompson, 1915, Amer. Ins. Galls: 10,40.

FEMALE.—Head light yellow rufous; antennae yellow rufous basally, hardly darker terminally, the third segment a third longer than the fourth; thorax light brownish rufous, more or less uniformly so; mesonotum sparsely punctate and sparsely hairy, only very minutely coriaceous between punctations; scutellum rugose but still sparsely hairy; lateral lines barely evident; without trace of a median groove; abdomen rufous brown or darker; all legs light yellow rufous, darker on tibiae; wing veins rather fine; first abscissa of radius without projecting tip at apex of angle; second abscissa of radius weakly bent at tip; areolet of moderate size; cubitus not reaching basalis; whole insect rather small, 2.2 to 2.8 mm. in length.

GALL.—As described for the genus, distinguished as follows: Color dark reddish brown, weathering dark to black, the old epidermis becoming quite ashy gray; individual galls up to 9.0 mm. in length and 6.5 mm. in diameter; the whole cluster up to 28. mm. in diameter.

HOST.—*Quercus grisea* (Kinsey coll.). *Q. arizonica. Q. oblongifolia. Q. Toumeyi* (acc. Weld, 1926; possibly more than one species of cynipid involved).

RANGE.—New Mexico: Hillsboro. (Kinsey coll.).

Arizona: Whetstone (galls, *Q arizonica).* Sabino Trail in Santa Catalina Mountains (galls, *Q. oblongifolia,* Kinsey coll. Also acc. Weld, 1926). Oracle *Q. arizonica,* Kinsey coll. Also acc. Weld, 1926). Huachuca Mountains, Mule Mountains, Santa Rita Mountains, Patagonia Mountains (acc. Weld, 1926).

Probably restricted to southernmost Arizona and immediately adjacent portions of New Mexico.

TYPES.—6 females, one cluster of galls, in Philadelphia Academy.

From Arizona, without locality (possibly from near Tucson where the collector lived); host indefinitely determined as "some variety of *Quercus virens*"; E. T. Cox, collector.

The present re-descriptions are based on paratypes from the Philadelphia Academy and on my own collection from Hillsboro, New Mexico. The original description is misleading in describing the parapsidal grooves as obscure, the foveae as very small, and the areolet as rather small.

LIFE HISTORY.—Adults: December 31, January 1, 24 (acc. Weld, 1926). Galls I collected at Hillsboro, New Mexico, on December 26, had all the live insects emerged and only dead insects remained in the galls.

This species appears to be the only American representative of

the complex, though we have galls of other species of the group from a wide area in western Mexico, as far south as Jalisco. *Spicatus* differs from its nearest Mexican relative, *strues*, in being smaller, in being less distinctly coriaceous between the punctations on the mesonotum, in lacking any trace of a median groove, in having the abdomen darker rufo-brown to black, the wing veins lighter in weight, the second abscissa of the radius only weakly bent at the tip, and the areolet larger. The galls of *spicatus* and *strues* are hardly distinguishable.

Spicatus was originally described as a species of *Loxaulus*. True *Loxaulus*, according to my studies, includes the genotypes of *Compsodryoxenus*. The genus (Mayr, 1881, Gen. gallenbew. Cynip. :9, 12, 33) was monobasic, with Bassett's species *mammula* as type; but *spicatus* is not at all closely related to true *Loxaulus*. Weld (1926, Proc. U. S. Nat. Mus. 68 (10) :45) recognized this error in assigning *spicatus to Loxaulus*, but made no re-assignment of the species.

Conobius (spicatus) strues, new species

agamic form

Fig. 1.

FEMALE.—Head light yellow rufous; antennae light brown, more yellow rufous basally, darker brown terminally, the third segment more distinctly longer than the fourth; thorax light brownish rufous, more or less uniformly so; mesonotum moderately punctate and scatteringly hairy, finely coriaceous between punctations, scutellum rather coarsely rugose and more hairy; lateral lines indicated by rather broad and smoother areas, but not conspicuous; sometimes with a trace of a very short median groove; abdomen rich rufous to brownish rufous, sometimes black at base dorsally; all legs light rufo-yellow, browner on tarsi, darkest brown on tibiae and on posterior tarsi; first abscissa of radius without projecting tip at apex of angle; second abscissa of radius with an expanded and distinctly bent tip; areolet small; cubitus hardly reaching basalis; whole insect quite robust, rather large, 2.5 to 3.2 mm. in length.

GALL.—As described for the genus; distinguished as follows: Color dark reddish brown, probably weathering darker; individual galls up to 9.0 mm. in length and 6.5 mm. in diameter; the whole cluster up to 23. mm. in diameter (Figure 1).

HOST.—*Quercus undata*, an evergreen white oak with ovate leaves which are soft pubescent beneath.

RANGE.—Chihuahua. Santa Isabel, 6 E, 6000′ (types).

Probably ranging through the Western Sierra of Chihuahua to the northern end of that state; possibly ranging southward to the state of Durango.

TYPES.—11 females, three clusters of galls (containing about 60 galls). Holotype, paratype females, galls; Kinsey collection.

Labeled: Santa Isabel, 6 E, 6000′, Chihuahua; galls October 24, 1931; females, March 1, 1932; *Q. undata;* Kinsey collector.

LIFE HISTORY.—Adults: March 1.

This insect is close to *spicatus*, from which it is, however, distinguishable by a number of characters. The whole insect of *strues* is larger, the mesonotum is more distinctly coriaceous between its punctations, sometimes there is a short indication of a median groove at the scutellum; the abdomen is more rufous, all of the tarsi and the hind tibiae are browner, the wing veins are heavy, the second abscissa of the radius has a distinctly bent tip, and the areolet is smaller. The galls are practically identical with those of *spicatus*.

Cynips (arida) conspecta, new species

agamic form

FEMALE.—Body color in general light brownish rufous, thorax nearly uniform in color, the insect darker in hardly any place except on abdomen which is rufous and piceo-rufous; antennae yellow rufous, dark brown on terminal third; parapsidal grooves more or less discontinuous, always more obscure near pronotum; mesopleuron rather shining but everywhere sparsely punctate and hairy; foveal groove more or less rugose; wings of normal length; all main veins medium brown; radial cell moderate in width, second abscissa of radius curved most near tip, tip of vein distinctly triangulate though mostly bent to one side; infuscation at base of radial cell very small; cubital cell almost entirely colorless, sometimes with the most obscure trace of a single mark; rather small insects 2.8 to 3.0 mm. in length.

GALL.—Similar to but readily distinguished from other galls of the complex. Mature gall almost strictly spherical, with a flat or slightly concave base; perfectly smooth, light red brown in color, with a white scurf which persists on at least part of the gall; up to 6.5 mm., averaging near 5.0 mm. in diameter.

HOST.—*Quercus Pringlei*, one of the several scrub oaks of the region; replaced on other scrub oaks in the same area by *C. rubella*.

RANGE.—Tamaulipas: Miquihuana, 7 SE, 6000′ (types).

Known only from this one locality in the southwestern corner of Tamaulipas.

TYPES.—3 mature females, 4 not fully transformed females, numerous galls. Holotype, paratype females, galls; Kinsey collection. Paratype galls: American Museum of Natural History, Museum of Comparative Zoölogy, Philadelphia Academy, U. S. National Museum.

Labeled: Miquihuana, 7 SE, 6000′, Tamaulipas: galls November 15, 1935; females without date; *Q. Pringlei;* Kinsey collector.

In our previous revision of the *Cynips arida* complex (Kinsey 1936, Ind. Univ. Sci. Ser. 4:217-237), the only species reported from the Eastern Mexican Sierra was *Cynips saxifera*, from a locality west of Ciudad Victoria, in the southwestern corner of Tamaulipas. From a few miles west of that same locality, from Miquihuana, which is still in Tamaulipas but immediately east of the main divides of the Sierra, we now have two more species to describe.

In this locality southeast of Miquihuana, there are several species of scrub or dwarf oaks, from three of which we have now bred insects of the present complex. Although these dwarf oaks are so closely related that it is often difficult to distinguish them in the field, we find that two perfectly distinct and not closely related insects are isolated on different oaks. The present species, *C. conspecta*, occurs on *Q. Pringlei*. As yet we do not have it from any other oak. It is *C. rubella* (described in the present paper) which occurs on the scrub oak, *Q. intricata*, and on the low dwarf, *Q. cordifolia*. The two cynipids are as different as the two most extreme forms in the *arida* complex. To note only a few of the differences: The galls of *conspecta* are nearly spherical, almost entirely smooth, and a bit smaller in average diameter; those of *rubella* are more hemispherical, distinctly shrivelled, and slightly larger in diameter. The insects of *conspecta* are almost uniformly brownish rufous, without any marks or blotches in the cubital cell, and with almost no infuscations at the base of the radial cell; the insects of *rubella* are red rufous with the lateral lines (and sometimes the anterior parallel lines) distinctly brown, and the splotches in the cubital cell and the infuscation at the base of the radial cell are distinct and of some size. *Conspecta* is most closely related to the *contacta-eluta-eminula* group of species from more southern Mexico;

rubella has its closest relatives in *saxifera*, from a more eastern part of the same Eastern Sierra, and in *saxulum*, from the Western Mexican Sierra. It is an interesting case of two branches of the one complex invading the one locality where they are, however, still separated by their restriction to different oak hosts.

From *contacta*, its geographically and evolutionarily nearest relative, *conspecta* is to be distinguished by the greater obscurity of the parapsidal grooves near the pronotum, by the fact that the cubital cell is entirely clear, and by its larger and more spherical gall. In *contacta* the parapsidal grooves are distinct to the pronotum, the cubital cell is heavily splotched, and the gall is distinctly dome-shaped. *Conspecta* and *contacta* agree in having the body uniformly light brownish rufous, in having the infuscation on the first abscissa of the radius very small, and in numerous other less prominent points.

Three of the 13 species now known in this complex have the cubital cell clear of all marks and splotches. Among the three, there is the most northern species in the complex, *C. conica* from northern Arizona; there is the most southern species in the complex, *C. fugiens* from Guatemala; and now we have this species *conspecta* from the central portion of the Eastern Sierra of Mexico. A consideration of all the characters of these three species makes it clear that they are not a phylogenetic unit. It would appear that this curiously distinct character—a clear cubital cell in a complex in which a heavily blotched cell is the rule—has arisen independently three times, in geographically remote portions of the continent. It should, however, be noted that the cubital cell splotches are smaller and lighter in all of the more southern Mexican members of the complex; so the complete loss of the markings is not such an unexpected development in the group.

Cynips (arida) rubella, new species

agamic form

FEMALE.—Body color in general red rufous, with the anterior parallel lines of the same color or with a touch of brown (never brown between the lines), the lateral lines more distinctly brown; antennae with terminal third or less dark brown; parapsidal grooves more or less distinct to pronotum (not always continuous); mesopleuron rather shining, but everywhere sparsely punctate and hairy; foveal groove more rugose than usual in the complex; wings of normal length; all main veins dark brown, radial cell not particularly broad; second abscissa curved only toward tip, tip of vein bent or slightly expanded; infuscation at base of radial cell not large but heavy; two splotches in cubital cell rather light, narrow, well separated; rather small insects 2.3 to 3.5 mm. in length.

GALL.—Similar to other galls of the complex. Mature galls more or less hemispherical, with a broadly flattened base, shrivelling considerably so gall is usually irregular in shape; light red or purple brown in color, with some white scurf; up to 7.0 mm., averaging near 5.5 mm. in diameter.

HOSTS.—*Quercus intricata* (types); *Q. cordifolia*. The first is a shoulder-high scrub white oak, the second, the lowest dwarf oak of the region. Replaced on *Q. Pringlei* in the same area by *C. conspecta*.

RANGE.—Tamaulipas: Miquihuana, 7 SE, 6000′ (*Q. intricata*, types. Also on *Q. cordifolia.*)

Not yet known beyond this one locality in the southwestern corner of Tamaulipas, in a central portion of the Eastern Mexican Sierra.

TYPES.—17 females, numerous galls. Holotype, paratype females, galls: Kinsey collection. Paratype galls: American Museum of Natural History, California Academy, Museum of Comparative Zoölogy, Philadelphia Academy, U. S. National Museum.

Labeled: Miquihuana, 7 SE, 6000′, Tamaulipas: galls November 15, 1935; insects without date; *Q. intricata;* Kinsey collector.

This is one of the two species representing the *arida* complex near Miquihuana, in the southwestern corner of Tamaulipas. See the discussion under the other species, *C. conspecta*, in the present paper. As noted in that discussion, *rubella* is found on *Q. intricata* and *Q. cordifolia*, while *C. conspecta* is found on *Q. Pringlei* in the same area. The two cynipid species are not closely related. *Rubella* is most closely related to the species *saxifera* and *saxulum*. *Saxifera* also occurs in the Eastern Sierra of Tamaulipas, just east of the locality from which we have *rubella*. *Saxulum* is a widespread species in the Western Sierra of Mexico, from southern Chihuahua through Durango.

Rubella differs from *saxifera* in not having so much brown on the thorax, the parapsidal groove is not always continuous, the foveal groove is more rugose, the second abscissa of the radius is not so curved, its tip not so broadly triangulate, and the infuscation at the base of the radial cell and the splotch in the cubital cell are not so heavy.

Rubella differs from *saxulum* in having the anterior parallel lines light brown or rufous, the parapsidal grooves are not always continuous, the foveal groove is more rugose, the radial cell is not as broad, the infuscation at the base of the radial cell is not as large, and the splotches in the cubital cell are not as large.

Cynips (mellea) sagata, new species

agamic form

FEMALE.—In color almost entirely piceous and black; antennae black, only the first two segments dark rufous; mesonotum sparsely, shallowly punctate and sparsely hairy, nearly smooth over much of area, rougher anteriorly; anterior parallel lines fine but fairly evident, lateral lines very obscure or lacking; median groove absent; scutellum quite a little longer than broad, finely rugose, its median ridge distinct, quite prominent; foveal groove quite broad, quite smooth and shining at bottom, distinctly divided into foveae; abdomen almost entirely black, hardly elongate, the second segment somewhat tongue-shaped, covering about two-thirds of abdomen; legs dark brownish rufous, touched piceous, hind tibiae and tarsi uniformly brown; wings of normal length; areolet rather small; cloud on first abscissa rather heavy, protruding from angle of vein into radial cell; tip of radius not at all enlarged; body of moderate size, 3.2 to 3.5 mm. in length.

GALL.—As described for the complex. Finally naked, or retaining part of the microscopic, stellate pubescence; flesh-colored to light brown, with considerable solid matter; rounded or flat basally, occurring singly on leaves.

HOSTS.—*Quercus oblongifolia* (types); and a tree form of *Q. breviloba*. In this area, these are the two most abundant tree-forms of white oaks.

RANGE.—Coahuila: Muzquiz, 7 SW, 3600′ (*Q. oblongifolia*, types.) Muzquiz, 5 SW, 3000′ (a tree form of *Q. breviloba*).

Probably restricted to the most northern end of the Eastern Sierra of Mexico.

TYPES.—2 mature females, 1 immature female, many galls. Holotype, paratype females, galls: Kinsey collection. Paratype galls: American Museum of Natural History, California Academy, Deutsches Entomologisches Institut, Museum of Comparative Zoölogy, Philadelphia Academy, U. S. National Museum.

Labeled: Muzquiz, 7 SW, 3600′, Coahuila; galls October 30, 1935; insects without date; *Q. oblongifolia;* Kinsey collector.

Previously we have described 11 species of this *C. mellea* complex (see Kinsey 1930, Ind. Univ. Studies 84-86:314-338; and Kinsey 1936, Ind. Univ. Sci. Ser. 4:238-241). All of these are from the southeastern quarter of the United States, except for the one species *rydbergiana* in the mountains of northern New Mexico. Elsewhere in our Southwest and throughout most of Mexico the complex is replaced by the

C. arida complex, and the relations of the two groups are so certain that we never expected to find the *mellea* complex in Mexico. It is, therefore, an item of some moment to have located a species of this Eastern American group south of the Rio Grande.

This Mexican species, *sagata*, comes from the northern end of the state of Coahuila, from just south of the Edwards Plateau of Central Texas. Further east in Mexico and in the southeastern corner of Texas, there is a great area of mesquite desert which is an absolute barrier to the interchange of eastern American and Eastern Mexican cynipid faunas. This oak-free area is about 350 miles wide. But there are, nevertheless, some instances of Eastern American affinities in the Eastern Sierra of Mexico; and it took a great deal of field work, spread over many years, to discover that there really are present-day connections between these two faunas. The complete story must be detailed elsewhere. Enough here to record that two of the Central Texan oaks, the live oak, *Q. virginiana*, and the scrub post oak, *Q. breviloba*, come close to the border in the neighborhood of Del Rio and a few points further west; that the live oak on the Mexican side is nearly continuous to the border in that same region; and that there is a taller tree (an undescribed species of oak) in the mountains of northernmost Coahuila which is so close to the Texan *Q. breviloba* that all of its cynipid fauna has Eastern Texan affinities. The present species, *C. sagata*, is the first of these *breviloba* relatives to be described from Coahuila.

One additional item of interest is involved in the fact that we have the present species, *sagata*, from this northern end of Coahuila, from both the *Q. breviloba* and from the *Q. oblongifolia* complexes. *Oblongifolia* is an oak of southern Arizona and northern Chihuahua. It is the only western oak that I have found in the northern end of the Eastern Sierra. Its presence there is probably due to the near approach of the Western and Eastern Sierra in northeastern Chihuahua and northwestern Coahuila. Nearly all of the cynipids on this *oblongifolia* relative in Coahuila have Western Sierran and Rocky Mountain affinities. The present instance of a cynipid with Eastern American affinities getting onto the western oak is a noteworthy exception to the rule.

The Central Texan species of the *mellea* complex is as yet undescribed. The galls of that Texan species and of the species from Coahuila are indistinguishable and, it is to be noted, rather distinct from the galls of the Eastern American species of the complex. These galls are, however, close to those made by *C. (mellea) rydbergiana*, which occurs in the northeastern corner of New Mexico (and adjacent Colorado?); and the insects of *sagata* and *rydbergiana* are closer than either species is to any of the Southeastern American species. In the key to the complex given in Kinsey 1930 (Ind. Univ. Studies 84-86:494-495), this species *sagata* would run to *rydbergiana*. *Rydbergiana* and *sagata* are unique in the group in showing a well-developed median ridge on the scutellum; both species are very largely black on the head, thorax, and abdomen; and both have antennae that are dark on all but the first two segments. The galls of the two are larger, more strictly spherical, smoother on the surface, and thicker-walled than the

galls of any other described species. In all these characters, however, *sagata* is still closer to the Central Texan species from *Q. breviloba.*

Sagata differs from *rydbergiana* in being almost entirely black, with practically no rufous on the thorax or abdomen; the antennae are black (instead of brown); the median ridge of the scutellum is more distinct and the foveae consequently more distinctly separated; and the legs are much darker brownish-rufous to piceous.

Cynips (nubila) lanaris, new species

agamic form

FEMALE.—Head rich rufous; antennae rich rufous on all but the terminal segments which are brown; thorax rich rufous, brown or blackish on anterior parallel and lateral lines, in foveal groove, and on lines between segments on sides, but rufous between anterior parallel lines; abdomen rich rufous and (largely) rufo-piceous; legs bright red rufous, nowhere black; median groove indicated right at scutellum; parapsidal grooves clearly complete to pronotum; infuscation on first abscissa of radius usually light near subcosta but heavy along a line leading from tip of angle of first abscissa of radius, giving the appearance of a median (longitudinal) vein extending out from that angle for a third of the way across the cell; expanded tip of second abscissa distinctly bent to one side; areolet large; smoky patches in cubital cell rather large, not heavy, not fused; large insects 3.3 to 4.7 mm. in length.

GALL.—Central core red-brown, densely covered with short, hair-like cells most of which are swollen at tip. Long, hair-like spines forming body of gall light straw white, tinged yellow; bases of these spines almost never swollen; these spines wavy for their whole length and densely set. Galls appear as loose tangles of hairs.

HOST.—*Quercus sacame.* This is the largest tree among the evergreen white oaks of the region.

RANGE.—Tamaulipas: Miquihuana, 7 SE, 6000′. Possibly extending for some distance through a more northern end of the Eastern Mexican Sierra, east of the main divides.

TYPES.—4 females, 3 galls. All in the Kinsey collection.

Labeled: Miquihuana, 7 SE, 6000′, Tamaulipas; galls November 15, 1935; females December 10, 1935, and without date; *Q. sacame;* Kinsey collector.

LIFE HISTORY.—Adults: December 10.

In our previously published revision of this complex (Kinsey, 1936, Ind. Univ. Sci. Ser. 4:243-258) we reported on nine species: two from southeastern Arizona, and seven from Mexico. Six of the Mexican species were from the Western Sierra and from the more southern Cordillera. Only one species, *nigricula,* was described from the Eastern Sierra—from the eastern part of San Luis Potosí. North of that point the Eastern and Western Sierras are widely separated, and this may explain the comparative rarity of the *nubila* complex in the Eastern mountains of Mexico. To the previously described list of species, however, we can now add two from this Eastern Sierra—one from northern Hidalgo, and one from southern Tamaulipas; but north of these northermost localities there are still 400 miles of Eastern Sierra in which we have not found this group.

In the previously published key to this complex (Kinsey 1936:246-247), the two species here described would run to sections 7 and 8; and the phylogenetic relations of the present species are clearly with *incompta, nigricula,* and *chica,* which appear in those sections of the key. This now gives us 5 species which have the parapsidal grooves continuous to the pronotum. As their geographic positions would lead one to expect, the present species are closest to *nigricula* and *incompta.*

We have *lanaris* from a locality near the southern end of the boundary between Tamaulipas and Coahuila. *Lanaris* is most closely related to the more southern species *molucrum* (described in the present paper). *Lanaris* differs chiefly in showing brown or black in the foveal groove; in having the infuscation on the first abscissa of the radius narrowed down to a slender band which projects like a vein from the angle of the first abscissa into the radial cell; and in having the central core of the gall covered with hair-like cells, most of which are swollen at the tips.

From the species *nigricula*, *lanaris* differs principally in having the antennae rich rufous on all but a few terminal segments, in showing rufous between the anterior parallel lines, and in the vein-like form of the infuscation on the first abscissa. The galls of *lanaris* and *nigricula* are essentially the same.

From *incompta*, *lanaris* is to be distinguished by the darker thoracic lines, the darker abdomen, and the vein-like form of the infuscation on the first abscissa. The galls of the two species are essentially the same.

Cynips (nubila) molucrum, new species

agamic form

FEMALE.—Head rich, rather dark rufous; antennae rich rufous on all but the terminal half dozen segments which are brown; thorax rich, rather dark rufous; black on anterior parallel and lateral lines, but not between anterior parallel lines and not on scutellum or sides of thorax; abdomen rich rufous and (largely) rufo-piceous; legs yellow rufous and brownish rufous, nowhere black; median groove indicated right at scutellum; parapsidal grooves clearly complete to pronotum; infuscation on first abscissa of moderate weight, extending a third of radial cell; expanded tip of second abscissa triangulate but small; areolet large to very large; smoky patch in cubital cell rather large, distinctly light, not fused; quite large insects 3.0 to 5.0 mm., averaging 3.9 mm. in length.

GALL.—Central core tan or brownish, densely covered with short, hair-like cells, none of which are swollen at tip; long, hair-like spines forming body of gall light straw white, tinged yellow and still more golden tan near tips; bases of these spines almost never swollen; these spines wavy for their whole length, and densely set. Galls appearing as loose tangles of hairs.

HOSTS.—*Quercus reticulata* (types); *Q. polymorpha*. Large-leaved, evergreen, tree forms of white oaks.

RANGE.—Hidalgo: Jacala, 5 W, 5000′ (types on *Q. reticulata*. Also on *Q. polymorpha*). Probably widespread through a central portion of the Eastern Sierra of Mexico, extending north from more northern Hidalgo.

TYPES.—175 females, many galls. Holotype, paratype females, galls: Kinsey collection. Paratype females, galls: American Museum of Natural History, British Museum, California Academy, Deutsches Entomologisches Institut, Field Museum, Museum of Comparative Zoölogy, Philadelphia Academy, U. S. National Museum.

Labeled: Jacala, 5 W, 5000′, Hidalgo; galls November 30, 1935; females without date; *Q. reticulata;* Kinsey collector.

The type insects were all cut from the galls, and the series includes transitional stages between pupae and adults, as well as many fully matured adults with wings more or less folded.

This insect was collected along the Laredo-Mexico City highway, near Jacala, in the northern end of the state of Hidalgo. It may range more or less widely through the Eastern Mexican Sierra; but the complex is represented by the species *nigricula* in the Eastern Sierra of San Luis Potosí, and by the species *lanaris*, newly described in the present paper, from the northern end of the Eastern Sierra in Coahuila.

The full extensions of these several ranges must, therefore, be determined by further collection. The characters of the present insect, *molucrum*, are closest to those of its nearest neighbors, *C. incompta*, *C. lanaris*, and *C. nigricula* (see Kinsey, 1936, Ind. Univ. Sci. Ser. 4:248, 251).

Incompta, *lanaris*, and *molucrum* are the only species out of the eleven in the complex which show rufous between the anterior parallel lines. From *incompta*, the insect of *molucrum* differs in having the thoracic lines almost always black (in *incompta* the mesonotum is often uniformly bright rufous); the head, thorax, and abdomen are a richer, darker rufous; the abdomen is distinctly darker rufo-piceous; and the expanded tip of the second abscissa is never as large. The galls of *molucrum* differ (from those of *incompta*) in having the central core tan rather than brownish red; and the hair-like processes covering the central core are almost never swollen.

From *nigricula*, *molucrum* differs in having the antennae light rufous on its basal two-thirds, in being rufous between the anterior parallel lines, in having no rufo-piceous on the thorax except on the anterior parallel and lateral lines, and in having a larger areolet. The gall of *molucrum* differs from that of *nigricula* in having the central core tan (not red-brown), and practically none of the hairs covering this core show swollen tips.

From *lanaris*, *molucrum* differs principally in being rufous in the foveal groove, in having an extensive infuscation on the first abscissa of the radius which extends continuously to the subcosta (and not merely in a vein-like projection from the angle of the first abscissa, as in *lanaris*), and in having the central core of the gall covered with short hairs which do not have swollen tips.

Cynips (plumbea) torosa, new species

agamic form

FEMALE.—Head, thorax, legs, and abdomen with a rich, dark rufous background, but with all lines and often most of rest of mesonotum including scutellum dark brownish black; abdomen largely or even entirely piceous; legs touched darker brown than in *texcocana;* antenna entirely rufous, hardly darker at tip; thorax only moderately hairy; foveal groove naked, undivided or with a fine, low division; entire abdomen hairy (except dorsally); wings distinctly smoky yellow; veins very heavy, dark brown; first abscissa of radius with a fairly heavy infuscation, margin of radial cell clouded but without a vein; cubital cell with marks faint, often reduced to a single longitudinal line parallel to second abscissa of radius; the largest insects in the complex, 3.3 to 5.2 mm., averaging near 4.5 mm. in length.

GALL.—Large, spherical, rarely flattened on a small base, not pointed; dull, slightly shrivelling, with a conspicuous, moderately heavy scurf (stellate pubescence) which is so persistent that even old galls are conspicuously bluish gray; denuded surfaces of galls light tan to dark purplish brown; up to 9.5 mm., averaging near 7.0 mm. in diameter.

HOSTS.—*Quercus rhodophlebia* (types); *Q. texcocana*. These are the two largest trees among the oaks of the region.

RANGE.—Mexico: Mexico City, 22 E, 8200′ *(Q. rhodophlebia, Q. texcocana)*.

Puebla: El Seco, 19 NE, 8500′ *(Q. rhodophlebia*, types). El Seco, 5 SW, 8200′ *(Q. texcocana)*.

Apparently restricted to the mountains east and southeast of Mexico City, ranging possibly into the state of Vera Cruz. Replaced south and west of Mexico City by *C. texcocana* Kinsey.

TYPES.—8 mature females, 4 not wholly mature females, numerous galls. Holotype, paratype females, galls: Kinsey collection. Paratype galls: American Museum of Natural

History, U. S. National Museum, Philadelphia Academy, Museum of Comparative Zoölogy, California Academy, Vienna Museum.

Labeled: El Seco, 19 NE, 8500′, Puebla; galls December 8, 1935; females without date; *Q. rhodophlebia;* Kinsey collector.

From several points in the mountains south and west of Mexico City we have *C. (plumbea) texcocana* (see Kinsey 1936, Ind. Univ. Sci. Ser. 4:205). From collections made 15 miles east of Mexico City, in January, 1932, we obtained three insects which look like good *texcocana;* but from the more extensive collections made 22 miles east of Mexico City in December, 1935, and from our collections made in the more southeastern state of Puebla we get a different insect, the present species *torosa.* The galls of *texcocana* and *torosa* are practically identical, but the insects are so different that there seems no chance of error in our determinations; and we must conclude that the more eastern and more western species meet in the Valley of Mexico, or else that our earlier record for *texcocana* from east of Mexico City involved some error in data. We have several other cases of cynipid groups represented by different species on the two sides of the Valley of Mexico.

Torosa has its closest relative in *texcocana.* From that species, *torosa* is best distinguished by its generally darker and richer rufous color, the greater extent of the piceous on the thorax and abdomen, and the larger body size. The insect of *torosa* is so much darker, and so distinctly larger that it is readily recognizable by the naked eye.

Disholcaspis (cinerosa) pallens, new species

agamic form
Fig. 2

FEMALE.—Antennae uniformly bright yellow rufous, either uniformly so or with brown on very tips; head bright red rufous; thorax light red rufous, with limited marks of brownish black (not deep black) on anterior parallel and lateral lines; abdomen rich rufous with some piceous or sometimes with considerable piceous black; legs largely rich rufous, brown on posterior tibiae; all wing veins very light yellow, peculiarly so; areolet very large; moderate-sized insects 3.3 to 4.1 mm., averaging 3.5 mm. in length.

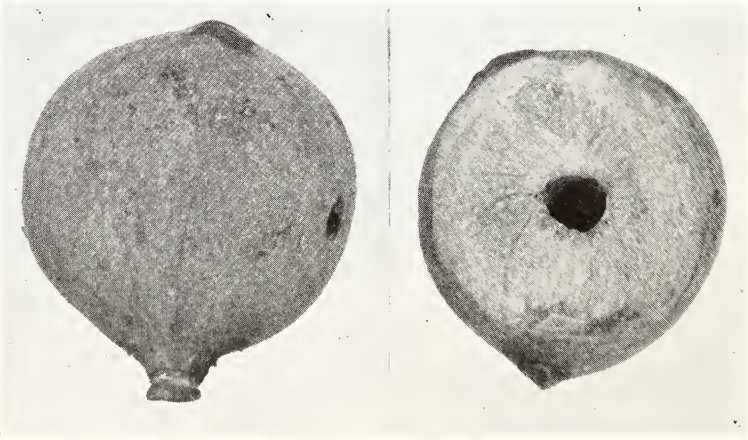

Fig. 2. Disholcaspis (cinerosa) pallens, new species
From Eastern Mexican lowlands, state of San Luis Potosí. Paratype galls, twice natural size.

GALL.—Practically identical with that of *Disholcaspis (cinerosa) cinerosa* (Bassett). Perhaps more often elongate and not as strictly spherical, more often drawn out to a slender point at base; averaging a bit smaller, up to 21.0 mm., mature galls averaging nearer 18.0 in diameter (Figure 2).

HOST.—*Quercus oleoides.* This narrow- and evergreen-leaved white oak is the common representative of the *Q. virginiana* complex in the northeastern portion of Mexico.

RANGE.—San Luis Potosí: Valles, 14 N, 900′.

Probably confined to a central portion of the more eastern Mexican lowlands, including the easternmost portions of the state of San Luis Potosí.

TYPES.—110 females, many galls. Holotype, paratype females, galls: Kinsey collection. Paratype females, galls: American Museum of Natural History, British Museum, California Academy, Deutsches Entomologisches Institut, Field Museum, Museum of Comparative Zoölogy, Philadelphia Academy, U. S. National Museum, Vienna Museum.

Labeled: Valles, 14 N, 900′, San Luis Potosí; galls November 27, 1935; females December 7, 14, 1935, January 1, 7, 8, 17, 20, 1936, and without date; *Q. oleoides;* Kinsey collector.

LIFE HISTORY.—Adults: December 7, 14, January 1, 7, 8, 17, 20. Two-thirds of the emergence over by the first of January, but goodly emergence continuing throughout most of January.

Two species of this complex have been previously described. The first, *D. cinerosa* (Bassett, 1881, Canad. Ent. 13:110) is widespread throughout the eastern two-thirds of Texas on the Texas live oak, *Q. virginiana. Disholcaspis unicolor* (Kinsey, 1920, Bull. Amer. Mus. Nat. Hist. 42:316) came from near Saltillo, in the northeastern part of Mexico. The present species, *pallens,* comes from a locality about 275 miles further south, halfway down the eastern Mexican coast and not far inland from Tampico. The locality, Valles, is on the Laredo-Mexico City highway. This is one of the relatively few cases of an Eastern American group having affinities in Eastern Mexico; for the host of the species, namely *Q. oleoides* of the *Q. virginiana* complex, belongs to one of the few groups of oaks which range without material interruption across the Rio Grande. An instance of a similar range on oaks of the *Q. breviloba* group is discussed under *Cynips (mellea) sagata,* newly described in the present paper. See *sagata* for a further discussion.

Pallens is most strikingly different from the previously described members of the complex in its very light yellow wing veins. It also differs in the several other ways given in the description above.

Disholcaspis (fungiformis) insulana, new species

agamic form

Fig. 3

FEMALE.—Antennae rather light yellow rufous, rather dark brown on terminal four or five segments; head and thorax light reddish rufous, more yellow rufous on sides of thorax, black on and between anterior parallel lines, on lateral lines, and in foveal grooves; anterior parallel lines almost entirely punctate, and lateral lines not particularly wide nor wholly smooth; entire foveal groove rugose at bottom; abdomen rich yellow piceous and dark brownish piceous; legs entirely light yellow rufous, nowhere darker; wing veins light yellow, browner on subcosta and first abscissa of radius, but very light and quite fine on other veins; radial cell rather slender; tip of second abscissa of radius fine, not expanded; areolet of moderate size to small; rather slender and distinctly small insects 1.7 to 3.0 mm., averaging near 2.4 mm. in length.

GALL.—A dense cluster of fungiform galls similar to those of *Disholcaspis fungiformis*

Fig. 3. Disholcaspis (fungiformis) insulana, new species
From Eastern Mexican Sierra, state of San Luis Potosí. Paratype galls, natural size.

Kinsey. Differing as follows: Usually topped with a slender and sharply pointed or broader tip which, however, is sometimes truncate, distorted, or lacking, the tips up to 7.0 mm. in length, the tip rising directly from the broader body of the gall which has a thin, irregularly circular rim extending about it, this apron more narrow, more irregular, more closely appressed against the body of the gall than in related species. There is no restricted neck or pedicel above or below this apron (as in the species *fungiformis).* The base of the gall rather small. Light red yellow when fresh, weathering to brown and black; entirely naked; individual galls averaging 7. mm. in diameter and 7. mm. high: the cluster consisting of up to 40 or more galls; the whole measuring up to 75. mm. in length and 17. mm. in diameter (Figure 3).

HOST.—*Quercus laeta,* the peach-leaved oak of the region.

RANGE.—San Luis Potosí: Rio Verde, 14 W, 5500′ (types).

Possibly restricted to this one mountain range west of Rio Verde, in the eastern part of San Luis Potosí.

TYPES.—801 females, many galls. Holotype, paratype females, galls: Kinsey collection. Paratype females, galls: American Museum of Natural History, British Museum, California Academy, Deutsches Entomologisches Institut, Field Museum, Museum of Comparative Zoölogy, Philadelphia Academy, U. S. National Museum, Vienna Museum.

Labeled: Rio Verde, 14 W, 5500′, S. L. P.; galls December 4, 1931; females December 6, 9, 1931, and February 10, 26, and "spring," 1932; *Q. laeta;* Kinsey collector.

LIFE HISTORY.—Adults: December 6, 9. Before February 10, and on February 26. Most of the emergence in January ("before February 10").

Disholcaspis (mexicana) largior, new species

agamic form
Fig. 4

FEMALE.—Insect for the most part rich red rufous, antennae brown, darkest terminally, rufous only on first two to six segments, black on anterior parallel and lateral lines, but with some rich rufous between anterior parallel lines; whole thorax coarsely puncto-rugose and densely hairy; foveae quite wide, distinctly rough at bottom; abdominal segments 3-6 distinctly punctate; areolet very large; insects large and distinctly robust; 3.2 to 5.0 mm., averaging near 4.3 mm. in length.

GALL.—Rosy to brownish tan, probably light and brighter when fresh, weathering darker brown; inner faces of galls which are pressed against other galls in the clusters are smooth and shiny, but exposed surfaces are very much wrinkled, and conspicuously reticulate; individual galls (in the rare instances where they occur singly) are more or less globose, but galls in compact clusters are very much compressed, making each one thin and flat with the exposed tops triangulate in outline; a whole cluster therefore with a surface much like that of an unopened pine cone; individual galls up to 24. mm. in diameter

Fig. 4. Disholcaspis (mexicana) largior, new species
From Western Mexican Sierra, state of Aguascalientes. Paratype galls, natural size.

and 19. mm. in height; whole clusters up to 83. mm. in length and 44. mm. in diameter (Figure 4).

HOST.—*Quercus rhodophlebia*, a large-leaved, evergreen white oak. Replaced on *Q. chihuahuensis* in the same area by *Disholcaspis (mexicana) mexicana*.

RANGE.—Pabellón, 20 W, 7000′ (types).

Probably restricted to a portion of the Western Sierra of Mexico, including the mountains of the state of Aguascalientes.

TYPES.—133 females, many galls: Holotype, paratype females, galls Kinsey collection. Paratype females, galls: American Museum of Natural History, British Museum, California Academy, Deutsches Entomologisches Institut, Field Museum, Museum of Comparative Zoölogy, Philadelphia Academy, U. S. National Museum, Vienna Museum.

Labeled: Pabellón, 20 W, 7000′, Aguascalientes; galls November 26, 1931; *Q. rhodophlebia;* Kinsey collector.

LIFE HISTORY.—Adults: mature at some unrecorded date after November 26 (probably within the next few weeks).

We found this insect occuring in the same locality with *Disholcaspis (mexicana) mexicana* (Beutenmüller), west of Pabellón, in the state of Aguascalientes; but *largior* was found on *Q. rhodophlebia*, while *mexicana* was found, in this region, on *Q. chihuahuensis*. The insects of *largior* differ from those of *mexicana* primarily in having the body richer rufous in color; the antennae are brown on all but the basal segments, while the antennae of *mexicana* are brown only at the tip; there is rufous between the anterior parallel lines of *largior*, while that area is largely black in *mexicana;* the thorax of *largior* is more coarsely

puncto-rugose and more densely hairy; the foveae are wider and more rough at bottom; and the abdominal segments are more distinctly punctate in *largior*. The insects of *largior* are so much larger and more distinctly robust than those of *mexicana* that it is possible to distinguish series of the two with one's naked eye. The galls of the two are even more different, for the individual galls of *mexicana*, even in compact clusters, are more globose and smooth and shining; while those of *largior* are conspicuously wrinkled and so distorted that they show triangulate ends in their cone-like clusters.

Neuroterus junctor, new species

bisexual form?

With the characters of the subgenus *Dolichostrophus* (see Kinsey 1923, Ind. Univ. Studies 58:78).

FEMALE.—Head, thorax, and abdomen almost entirely black, lower part of face and mouthparts rufo-yellow, antennae of fair weight, dark brown with first two segments very light yellow, with 13 segments, the third segment straight, not long but more than one and a half times the length of the fourth; thorax somewhat longer than high or wide; mesonotum including scutellum and mesopleuron superficially smooth and naked, but very microscopically crackled; abdomen no longer than high, hardly produced dorsally; legs brownish piceous on coxae and on most of femora, straw yellow on all joints and on trochanters, and rufo-yellow on tibiae and tarsi; wing veins moderately slender, well defined, medium brown; areolet quite large; basalis without a brownish cloud; terminal portion of subcosta rather long, but radial cell entirely open; length near 1.7 mm.

GALL.—Irregular, monothalamous or polythalamous swellings in the blade of the leaf, wholly inseparable, well developed on both surfaces of the leaf, though more developed on the under surface; covered with a short but dense pubescence, each gall separable or more or less fused with other galls.

HOST.—*Quercus texcocana.*

RANGE.—Mexico: Mexico City, 12 W, 8500′ (types).

TYPES.—2 females, one cluster of galls, in the Kinsey collection.
Labeled: Mexico City, 12 W, 8500′ D.F.; gall January 13, 1932; female March 15, 1932; *Q. texcocana;* Kinsey collector.

LIFE HISTORY.—Adults: March 15 (possibly of a bisexual, possibly of an agamic generation).

This insect provides an important link between two complexes which were recognized as related, but not understandably connected by the previously described American species. The first, the *irregularis* complex, is confined to the Eastern half of the United States. The second, *Neuroterus decipiens*, is a single species known only from California. The gall of *junctor* is very much like the galls of the *irregularis* complex, but the insect is closer to *N. decipiens*—in fact, closer than any species of the *irregularis* complex. It has been puzzling to understand how the Eastern American group, *irregularis*, could have a close relative, *decipiens*, in California, when neither group is represented in the Rocky Mountain area; but with this new species *junctor* as a clue, we shall direct our search into Mexico for the connecting links between the American complexes.

Since both *irregularis* and *decipiens* are known only from bisexual forms, it is quite possible that *junctor* represents a bisexual generation; but this is not determinable either from our limited material or from the collection and breeding dates with our series.

Neuroterus (niger) reconditus, new species

agamic form

With the characters of the subgenus *Diplobius* and the *niger* complex (see Kinsey, 1923, Ind. Univ. Studies 58:35, 41).

FEMALE.—Head, thorax, and abdomen dark piceous black; antennae rather light brown, yellowish on basal segments; legs dark brown, straw yellow on all joints and on trochanters and tarsi; wing veins very light brown; aerolet rather small; abdomen globose-triangulate, not produced dorsally or ventrally, rather crinkled; length 0.6 to 1.0 mm., averaging near 0.7 mm.

GALL.—Minute, inconspicuous pustules in the blade of the leaf; somewhat circular or more ovoid in shape, equally developed on both surfaces of the leaf, inconspicuous on both, but more conspicuous above because of the nature of the upper surface of the leaf; gall surface naked, without irregularities other than those normal to the leaf surface; fresh galls of the same color as the leaf, old galls becoming browner sooner than the rest of the leaf; averaging 1.0 mm. in diameter. Galls fairly numerous on single leaves.

HOST.—*Quercus macrophylla*, the largest-leaved white oak of the area.

RANGE.—Aguascalientes: Pabellón, 20 W, 7090′ (types).

Probably confined to a portion of the Western Sierra in Mexico, including the state of Aguascalientes.

TYPES.—50 females, numerous galls. Holotype, paratype females, galls: Kinsey collection. Paratype females, galls: American Museum of Natural History, California Academy, Museum of Comparative Zoölogy, Philadelphia Academy, U. S. National Museum.

Labeled: Pabellón, 20 W, 7000′, Aguascalientes; galls November 26, 1931; females April 10, 1932; *Q. macrophylla;* Kinsey collector.

LIFE HISTORY.—Agamic females: emerging April 10.

The *niger* complex has been known from the eastern U. S., from our Southwest (but not from the Rockies further north), and from California. The present species is the first to be described from Mexico. Like all the other described species of the group, *reconditus* differs chiefly in the minor color characters noted above; but the form of the gall provides some further basis of differentiation of the species.

Neuroterus (verrucarum) visibilis, new species

agamic form

With the characters of the subgenus *Diplobius* and the *verrucarum* complex (see Kinsey 1923, Ind. Univ. Studies 58:35, 67).

FEMALE.—Head, thorax, and abdomen usually jet black, sometimes touched piceous in places; antennae weak, light brown terminally, straw yellow basally; legs light brown, joints and tibiae straw yellow; mesonotum including scutellum and mesopleura entirely smooth, not showing any crackling even under high powers of microscope; abdomen globose-triangulate, about as high as long, not protruding dorsally, sometimes a bit protrudent ventrally; wing veins very light, only tinged brownish; areolet moderate or smaller; very small insects 0.6 to 0.9 mm., averaging near 0.75 mm. in length.

GALL.—Very minute, elongate-oval, hard but thin-walled cells; with a slightly elevated, circular apex in center of top surface; surfaces of galls minutely granular; each cell attached by a broad area to under surface of leaf, producing a barely evident elevation of upper surface of leaf, but cells not embedded in such a depression of under surface (*i. e.*, an elevation of upper surface) as is usual in the American species of the complex; cells sparsely hairy with rather long trichomes, this clothing however no heavier than that normal to under surface of leaf; cells averaging 0.8 mm. in length and 0.4 mm. in diameter. Galls abundant on single leaves.

HOST.—*Quercus macrophylla*, the largest-leaved white oak of the area.

RANGE.—Guanajuato: San Felipe, 8 NE, 7000′ (types).

Probably throughout a more central area in Mexico, including the state of Guanajuato.

TYPES.—346 females, many galls. Holotype, paratype females, galls: Kinsey collection. Paratype females, galls: American Museum of Natural History, British Museum,

California Academy, Deutsches Entomologisches Institut, Field Museum, Museum of Comparative Zoölogy, Philadelphia Academy, U. S. National Museum, Vienna Museum.

Labeled: San Felipe, 8 NE, 7000′, Guanajuato; galls December 6, 1931; females March 6, 14, 25, 1932; *Q. macrophylla;* Kinsey collector.

LIFE HISTORY.—Adults: March 6, 14, 25.

The *verrucarum* complex has been known previously only from the eastern half of the United States. The present species, and the two that follow, extend the records through the Western Sierra to the southwestern corner of Mexico. This is the first instance of an exclusively Eastern American group occurring in the Western Sierra of Mexico.

The gall of *visibilis* is, however, hardly different from the seed-like galls of the *saltatorius* complex (which are known both from the Eastern and the Western United States). None of these Mexican species has the gall embedded in as deep a depression as is common in the American species of the group, and the mode of attachment of this larval cell and the extent of the hairy covering of the gall are, after all, the chief differences between the *verrucarum* and the *saltatorius* complexes. Since the insects of the two groups differ in very few respects, it is not unlikely that these Mexican species will provide connecting links between them.

The insect of *visibilis* is to be distinguished from the other Mexican species described in the present paper by its very much smaller size, by the fact that the abdomen is not produced dorsally and usually not produced ventrally, and by its complete lack of crackling on the thorax (as seen by the same high powers that show crackled surfaces on the thoraces of *volutans* and *vulpinus*).

Neuroterus (verrucarum) volutans, new species

agamic form

With the characters of the subgenus *Diplobius* and the *verrucarum* complex (see Kinsey 1923: Ind. Univ. Studies 58:35, 67).

FEMALE.—Head, thorax, and abdomen almost entirely black, lower part of face piceo-rufous; antennae weak, dark brown, yellowish brown basally, with 13 segments, the third segment straight, not long but more than one and a half times the length of the fourth; thorax somewhat longer than high or wide; mesonotum including scutellum and mesopleuron superficially smooth and naked, but very microscopically crackled; abdomen triangulate, higher than long, more or less protruding ventrally; ovipositor often to brownish yellow on all joints and all tibiae; wing veins light brown; areolet of medium size only; cubitus faint but continuous to basalis; terminal portion of subcosta rather long, but radial cell entirely open; medium-sized insects 0.8 to 1.5 mm., averaging nearly 1.2 mm. in length.

GALL.—Minute, elongate-oval, hard but thin-walled cells with a slightly elevated apex in center of top surface; surfaces of galls minutely granular, each cell attached by a broad area to the under surface of the leaf, producing an inconspicuous, smooth but hardly elevated area on the upper surface of leaf; galls not embedded in any deep depression of under surface of leaf such as is characteristic of the American species of the complex; cells fairly well covered and more or less hidden by a circular tangle of long, brown trichomes which more or less contrast with the normally hairy under-surface of leaf; cells averaging 1.4 mm. in length and 1.0 mm. in diameter, the whole mass of hairs on each gall averaging 2.0 mm. in diameter. Galls often densely covering under surfaces of leaves.

HOST.—*Quercus texcocana*, the smaller-leaved tree which is the commonest white oak in the mountains about the Valley of Mexico.

RANGE.—Mexico: Mexico City, 17 S, 8200′.

TYPES.—230 females, many galls. Holotype, paratype females, galls: Kinsey collection. Paratype females, galls: American Museum of Natural History, British Museum, California Academy, Deutsches Entomologisches Institut, Field Museum, Museum of Comparative Zoölogy, Philadelphia Academy, U. S. National Museum, Vienna Museum.

Labeled: Mexico City, 17 S, 8200′, D.F.; galls January 12, 1932; females March 7, 14, 1932; *Q. texcocana;* Kinsey collector.

LIFE HISTORY.—Agamic females: March 7, 14.

The gall of *volutans* is superficially quite like those found in the *verrucarum* complex in the United States. Upon closer examination it will be seen to differ in having no real depression in which the larval cell is sunk—and consequently no great elevation on the upper surface of the leaf. From the related Mexican species, *volutans* differs as follows: From *visibilis*, in being distinctly larger, in showing a microscopic crackling on the thorax, and in having the abdomen somewhat produced dorsally. From *vulpinus*, in being a bit larger, in having the thoracic crackling a bit more evident, in having the abdomen produced dorsally instead of ventrally, and in having both the antennae and legs darker both in their brown and in their lighter colorings.

Neuroterus (verrucarum) vulpinus, new species

agamic form

With the characters of the subgenus *Diplobius* and the *verrucarum* complex (see Kinsey, 1923, Ind. Univ. Studies 58:35, 67).

FEMALE.—Head, thorax, and abdomen nearly jet black, touched piceous in a few places; antennae weak, light brown terminally, straw brown basally, with joints between basal segments very light straw; legs in part medium brown, both ends of all segments and all of tibiae light straw yellow; mesonotum including scutellum and mesopleuron entirely smooth, showing an indefinite crackling only under high powers of microscope; abdomen triangulate, higher than long, more or ess protruding ventrally; ovipositor often long protruded; wing veins light brownish straw; areolet of moderate size or a bit smaller; insect 0.8 to 1.2 mm., averaging a little less than 1.0 mm. in length.

GALL.—Minute, elongate-oval, hard but thin-walled cells, usually with a slightly elevated apex in center of top surface; surfaces of galls minutely granular, each cell attached by a broad area to the under surface of the leaf, not buried in the sort of depression characteristic of American species of the group, and showing no deformation unless a slight discoloration on upper surface of leaf; cells densely covered and entirely hidden by a circular tangle of long, whitish trichomes which contrast sharply with the normally hairy under surface of leaf; cells averaging 0.7 mm. in length and less in diameter, the whole mass of hairs on each gall averaging 2.5 mm. in diameter. Galls densely covering under surfaces of leaves.

HOST.—*Quercus macrophylla*, the larger-leaved white oak of the area.

RANGE.—Guerrero: Taxco, 8 NE, 8000′.

Probably confined to a southwestern portion of Mexico including at least a portion of the state of Guerrero.

TYPES.—33 females, numerous galls. Holotype female, paratype females, galls: Kinsey collection. Paratype females, galls: American Museum of Natural History, U. S. National Museum, Philadelphia Academy.

Labeled: Taxco, 8 NE, 8000′, Guerrero; galls January 7, 1932; females April 10, 1932, *Q. macrophylla;* Kinsey collector.

LIFE HISTORY.—Agamic females: April 10.

The gall of *vulpinus* is more densely hairy and, in its contrast with the normal surface of the leaf, more like the galls of the American species of the complex, than either of the two other species now described from Mexico. The larval cell is, however, still not in a depression, and there is, therefore, no elevation on the upper surface of the

leaf. The insect of *vulpinus* differs from that of *volutans* (its nearest described relative) in being a bit smaller, in having the thoracic crackling not quite as evident, in having the abdomen produced ventrally instead of dorsally, and in having the antennae and legs somewhat lighter in both of their colors.

Neuroterus (saltatorius) tumba, new species

agamic form

With the characters of the subgenus *Diplobius* and the *saltatorius* complex (see Kinsey 1923: Ind. Univ. Studies 58:35, 45).

FEMALE.—Head, thorax, and abdomen piceous black; cheeks narrow, eyes of moderate size; antennae with third segment nearly twice as long as fourth, mesonotum and mesopleuron entirely smooth, abdomen not as long as high, slightly produced dorsally; antennae dark brown, straw yellow basally; legs dark brown, all joints, trochanters, and tarsi straw yellow; cubitus very faint or discontinuous; areolet of moderate size; length 0.8 to 1.5 mm., averaging near 1.1 mm.

GALL.—An ovoid, naked cell, broadly attached to under surfaces of, and hence only poorly separated from the leaf. Cells averaging 1.5 mm. in length and 1.2 mm. in diameter, thin- but hard-walled, surface rough, the roughening sometimes more or less radiate from apex of gall, without hairs or other covering; each gall mounted on a slight elevation of under surface, and hence causing a distinct depression of upper surface of leaf. Galls usually abundant on single leaves.

HOST.—*Quercus macrophylla*, the larger-leaved white oak of the area.

RANGE.—Guerrero: Chilpancingo, 6 S, 4000′.

TYPES.—7 females, numerous galls. Holotype, paratype females, galls: Kinsey collection. Paratype galls: American Museum of Natural History, Museum of Comparative Zoölogy, Philadelphia Academy, U. S. National Museum.

Labeled: Chilpancingo, 6 S, 4000′, Guerrero; galls January 8, 1932; females March 24, 1932; *Q. macrophylla;* Kinsey collector.

LIFE HISTORY.—Agamic females: March 24.

This is the first insect of the *saltatorius* complex described from Mexico. The complex has previously been recorded from Eastern, Southwestern, and Pacific areas of the United States. The galls of *tumba* are most like those of *N. (saltatorius) saltarius* which Weld described from Indiana, and they are still more like undescribed species from Texas. It is interesting to find Eastern American, instead of the usual Rocky Mountain affinities, in this Southwestern corner of Mexico.

Notes on the Bionomics of Roaches Inhabiting Houses

George E. Gould and Howard O. Deay, Purdue University

Cockroaches are gregarious and are usually found in the kitchen and other places where food is stored. All of our species are nocturnal in habit, hiding away in dark, damp, warm places during the day and coming out at night in search of food. Of the six species found in Indiana homes, the German roach (*Blatella germanica* (Linn.)), the American roach (*Periplaneta americana* (Linn.)), and the Oriental or black roach (*Blatta orientalis* Linn.) are common household pests; and, because of their frequent occurrence around sinks and water pipes, all three have had the common name of "Water bugs" applied to them. A tropical species, the brown-banded roach (*Supella supellectilium* (Serv.)), which was first found in Indiana at Bloomington in October, 1937, shows a preference for staying in furniture, bedding, and closets, and behind picture mouldings, etc. The Pennsylvania wood-roach (*Parcoblatta pennsylvanica* (De Geer.)) has been found in many rural and urban homes where it has migrated from nearby wooded areas. The smoky brown roach (*Periplaneta fuliginosa* (Serv.)) is a subtropical species and has been found breeding throughout the year in greenhouses. It has been reported as a household pest in Iowa[1].

The German roach is the most common and abundant species in dwelling houses. It increases more rapidly than do other roaches because it produces more eggs per capsule, and the young complete their growth in a shorter period of time. The time required for a complete generation is about 90 days for eggs produced in July, and about 130 days for eggs produced from September to April. The small size of this species enables it to crawl into cracks and crevices. In an infested home it is confined to the kitchen and lavatories where it hides behind baseboards, in cupboards, iceboxes, and dark corners, and around water pipes. The German roach is quite active, but it seldom flies. When it does, its flight is of a gliding nature.

The American roach, the largest of the house-infesting species, has a long developmental period requiring from 300 to 500 days. It is more common in restaurants, grocery stores, and packing houses than in homes, where it usually hides in the kitchen or basement. At night it wanders about through the infested premises, and during the summer nearby yards and alleys may be overrun with it. It has fully developed wings, but its rare flights are sluggish.

The Oriental roach is the most loathsome of the household forms as it travels through sewer pipes and lives on filth. It feeds on a wide range of organic matter and remains in dark, damp basements most of the time. This species enters the home through sewer and drain pipes and is rarely seen. The males have full wings and probably can

[1] Fulton, B. B., 1928. Cockroach destruction in buildings. Iowa Agri. Expt. Sta. Cir. 112.

fly, but the females have rudimentary wings and are comparatively sluggish. The developmental period is about a year and the adults live nine to twelve months.

The brown-banded roach is similar in shape and size to the German roach and, like it, is quite active. It has a tendency to fly when disturbed. Except when in search of food, it seldom visits the kitchen and confines its activities to other parts of the house. Egg capsules are often stuck under furniture and in closets. There are possibly two generations of this species a year in warm houses.

The wood-roach is a common inhabitant of woods where it lives under the bark of dead and fallen trees. In rural areas where a house is surrounded by or near a woods, these roaches are common invaders. The males are capable of long flights, while the females may migrate some distance by crawling. During the past summer a trip was made to investigate an infested farm house. Many mature males and a single female were found on an inclosed back porch, and a few males were in the house, but there were no young anywhere. About dusk the roaches began flying in short flights around an old building used for a garage and chicken house. By watching carefully, an occasional roach was observed to fly to the house which was about 40 feet away or to the woods which was about 100 feet in the other direction. This species is the one frequently encountered by motorists driving by woods about dusk. In nature the wood-roach passes the winter as a partially grown nymph, and even in zero weather is quite active when exposed by pulling away bark. Adults are present from May until early October.

The smoky brown roach is regarded as a household species, although records from Indiana show it to be present and breeding in a greenhouse. In the same location the American roach is common, and so it undoubtedly finds sufficient organic matter for its food requirements. It is quite active and capable of flying.

In maintaining living colonies of these six species, all are reared in gallon-size glass battery jars on a mixed food known as Haydak's mixture[2], consisting of corn meal, whole-wheat flour, wheat bran, dried skim milk, powdered yeast, honey, and glycerin. Raw potato is given them once a week, and water is present at all times. The rearing jars are kept on a laboratory table, and, after a few days, daylight does not seem to bother the roaches. An inch band of vaseline around the top, inside of the jars, is an effective barrier to prevent the escape of all species except the German and the brown-banded roaches. Adults of the Oriental roach, and some nymphs are unable to crawl up the sides of the glass jars.

The food requirements of roaches are not restricted, as they seem to thrive on a wide variety of organic material. The American roach was maintained for over a year on a diet of raw potatoes alone. When given a choice of several foods, this species was attracted to chocolate and to a mixed food containing honey. In trapping, bananas proved to be the best bait, although at a meat packing house roaches were readily attracted to hamburger. Commercial bait containing cereals,

[2] Haydak, M. H., 1936. A food for rearing laboratory insects. Jour. Econ. Ent. 29:1026.

honey, and phosphorus attracted the American roach in large numbers, but, when arsenicals were used in a similar mixture, the roaches would not feed.

Thermal-gradient tests were conducted to determine the temperature range preferred by the American and Oriental roaches. The chamber used was six feet long and about four inches square. One end was placed on a hot radiator and the other end packed in a salt and ice mixture. Thermometers were placed 10 inches apart for obtaining records in various sections. Twenty roaches were released in the chamber in each test and allowed 30 minutes to find the most suitable temperature. A number of tests performed with different sets of roaches indicate that both species prefer a temperature between 79° and 82° F. in a chamber where maximum range was from 40° to 99° F. In one test, five American roaches ran down to the cold end and in a few minutes fell over on their backs numbed.

Although the processes of capsule formation and egg-deposition inside the capsule are similar in all six species, the number of eggs per capsule and the care of the capsule varies. In the capsule of the American and Oriental roaches there is a maximum of 16 eggs, in the brown-banded roach 18 eggs, in the smoky brown roach 24 eggs, in the wood-roach 32 eggs, and in the German roach 42 or 44 eggs. Less than 24 hours are required for capsule formation and egg deposition in it, and as a rule the first five species will deposit the capsule before the 24-hour period is ended. In captivity the roaches deposit the capsule on paper, on food, or on the side of the jar. Capsules are usually glued in place by secretions from the mouth of the roach, and in most cases are covered by a coating of small bits of paper, pieces of food, or pellets of excrement. The wood-roach takes less care of its capsules, which are often found loose in the jar.

The female German roach differs from those of the other five species in that she does not deposit her capsules but carries them until hatching. In the deposition of eggs in the capsule, the process is similar to that of the other species, that is, the seam is uppermost and the eggs are placed in it head-end up. About 12 hours after egg laying is completed, the capsule gradually shifts over on its side so that the seam is usually to the right. The actual hatching of the eggs has been witnessed by the writers only once. The capsule split open along the seam, and the white heads of the numerous young roaches appeared. After much struggling and squirming, about 12 worked themselves out and soon were pulling their antennae and legs free from their individual egg shells. They then dropped to the bottom of the jar and remained motionless for a few minutes. Their struggles to free themselves had taken approximately five minutes. At the same time, the adjoining young roaches were working themselves free, so that at the end of ten minutes 32 young were on the bottom of the jar, and two were still struggling to free themselves. After remaining motionless for a minute or two, their inflated, elongate shape disappeared, and the roaches became flattened and somewhat oval in shape and ran around the jar normally. Several of the young crawled up on their mother and ate the egg shells pro-

truding from the open seam of the capsule and even ate the head of an unfortunate mate that was unable to free itself of its egg shell.

The actual mating of cockroaches has not been observed, although courtship is a common occurrence at night, and on one occasion a pair of American roaches was found coupled together. When the capsule attached to the German roach described in the preceding paragraph started to hatch, the five males in the same jar became quite excited and made numerous attempts to mate with her. Time and time again they would approach the female but were kept at a distance by the constant twitching of her antennae. Then the males would turn around, and, with their wings at right angles to the body and the abdomen greatly extended, would attempt to back under the body of the female. These attempts were usually made from in front, although often the approach was made from the side.

Cannabalism among roaches, especially when they are crowded, is common in the laboratory. American roaches frequently attack one that is injured or unable to extract itself from its old skin in the act of molting. When food is scarce, the injured roach is often completely consumed except for wings, legs, and antennae. It has been noted also that when adults are dying in jars where insecticides are being tested, other roaches often eat into their abdomens. German roaches often attack newly molted nymphs and cause them to deflate.

Although roaches are considered the most loathsome insect invaders of the home, they are exceedingly clean about removing any foreign material on their body. A little dust on an antenna will set the roach to cleaning this appendage and often other parts of the body. The skill by which the roach hooks a front leg over an antenna, draws it down into its mouth, and then by rapid movements of the mandibles forces it between the upper and lower lips, is truly remarkable. Any foreign particle on the antenna is scraped off on the exterior of the lips and seldom enters the mouth. In order to clean the legs or the underside of the abdomen, the roach arches its back and uses its mouth to remove the source of irritation. An attempt was made to mark individual nymphs by placing black lacquer or shellac on their backs, but these materials would always peel off in a day or so. However, it was quite amusing to watch a roach attempt to remove this shellac by arching its back and rubbing it against the glass jar much as a cat rubs against a person's leg.

In order to determine if roaches can reproduce parthenogenetically, observations were made on four virgin female American roaches and one German. Two of the American roaches produced no capsules, a third produced a single imperfectly formed capsule, and the fourth two capsules, one imperfect and one perfect in size but light in color. The German female produced three capsules, the first being eaten after two days, the second after 38 days, and the third remaining attached when the female died after 30 days. None of the eggs in these capsules were fertile.

A Cat With an "Upside-Down Stomach"

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On January 9, 1937, an embalmed cat was dissected in the Purdue Laboratory. This cat, a male, was apparently a young adult and showed externally no abnormal conditions except a somewhat enlarged thorax and a constricted lower abdomen. Dissection, however, revealed a strange distribution of the internal organs.

Figure 1 shows the arrangement of the viscera as they appeared with the ventral part of the body wall removed.

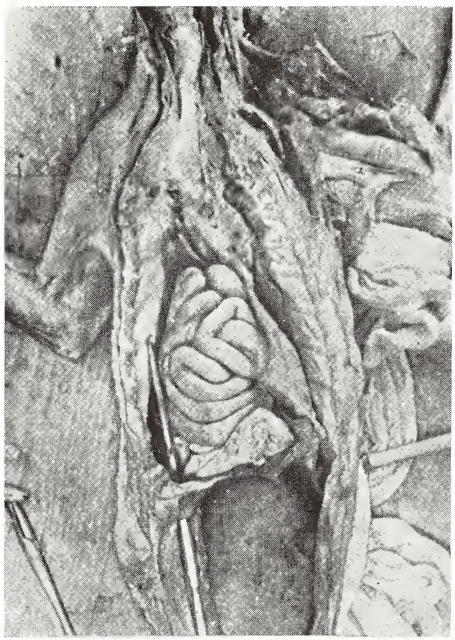

Fig. 1.

Nearly the entire small intestine was crowded into the right pleural cavity, having entered through a hole in the diaphragm approximately one inch in diameter. The figure shows a probe thrust through this opening which was located dorsally and at the right side. The intestine and lung occupied the cavity together with no membrane separating them. The spongy condition of the lung indicated that it had functioned during life presumably in a normal manner. The pancreas and spleen were found also in the lung cavity, somewhat malformed and large, but otherwise apparently normal. They were attached to the great omentum which was partly in the plural cavity. The stomach, about two inches of the duodenum, a three-inch fold of the jejunum, the lower two inches of the ileum, the large intestine, and the liver were below the

diaphragm. The right part of the liver, which was the smaller, consisted of two lobes, the left part of four.

Fig. 2.

Only one kidney, the left, was found. It was large, about three times the size of a normal kidney. There were, however, two straw-colored bodies (Fig. 2) found connected by a twisted thread and lying unattached in the dorsal part of the abdominal cavity. One was about seven-eighths of an inch long and ellipsoidal in shape. The other was about half as large and roughly spherical. The surface of both bodies was rough, appearing similar to the bumpy exterior of a cucumber. When sliced, they were found to have a cheesy consistency. It is thought that they may have been the remains of the missing kidney.

This condition in man is described by Arey[1] and called a diaphragmatic hernia. Persons so affected have been referred to popularly as having an "upside-down stomach." It is said to occur most often in man on the left side, in contrast to the present instance in the cat which was on the right.

Diaphragmatic hernia arises not as the result of an accident in adult life as might be supposed, but rather it is a developmental anomaly in which the pleuro-peritoneal membrane may fail to unite properly with the edge of the septum transversum to form the diaphragm. Thus, an opening is left through which some of the abdominal viscera may protrude into the thoracic cavity.

It is possible that diaphragmatic hernia may not be extremely rare in cats; Dr. W. P. Morgan of Indiana Central College informs me that he has observed this condition at his laboratory in a cat that was taken in Indiana. The specimen described in this paper was obtained from a supply house in Rochester, N. Y.

[1] Arey, L. B., 1924. Developmental anatomy. W. B. Saunders, Philadelphia.

Respiration Studies With Fresh-Water Molluscs:

I. Oxygen Consumption in Relation to Oxygen Tension

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The following investigations were carried out with the purpose of determining, first, the rate of oxygen consumption of molluscs in relation to the oxygen tension of the surrounding water, and second, to what low tensions oxygen consumption could progress. Numerous trials were made, and the most significant are recorded in this paper.

Such determinations have been recorded by other investigators with other forms of animal life. In a previous paper, Hyman (1929) has given a summary of the results of other workers. For the sake of brevity, her summary and bibliography are omitted here with the exception of those applying to the Mollusca and certain other forms recently investigated. The aquatic molluscs investigated by others have been shown to maintain oxygen consumption uniformly at lowered tensions. Amberson et al. (1924) have shown that oxygen consumption of *Loligo pealii* is constant to 30% saturation of the water. Henze (1910) has reported oxygen consumption of *Limax agrestris*, a terrestrial slug, lowered at 5 to 15% oxygen. Thunberg (1905) reports oxygen consumption of the same form increased at 50 to 97% oxygen. Other molluscs able to respire uniformly at reduced tensions are *Anodonta* (Dakin and Dakin, 1925), *Buccinium*, *Aplysia*, *Fusus* (Moore et al., 1912), *Aplysia* and *Eleodone* (Henze, 1910).

The author (1931) working with aquatic insects, found that the nymphs of the dragon-fly, *Nasiaeschna penthacantha*, were able to respire at a fairly uniform rate to tensions of about one-sixth that of normal equilibrium of air and water. The same was true of the larvae of the caddis-fly, *Limnephilus rhombicus*. Increasing the percentage of dissolved oxygen in the water above normal equilibrium did not increase the respiration rate of this species.

Hall (1931) reports that oxygen consumption of the worm, *Urechis caupo*, is independent of oxygen pressures down to a value of 70 mm. of mercury. Lindemann (1932) reports a "straight-line" relationship between oxygen consumption and oxygen tension in the leech, *Hirudo*. Hiestand and Singer (1934), also using *Hirudo*, find oxygen consumption to be independent of oxygen tensions above normal air-water equilibrium but slightly dependent upon tensions below air-water equilibrium. They report cessation of oxygen consumption at about 0.8 mgm. oxygen per liter or approximately one-tenth that of normal water. More recently, Maloeuf (1936), using a closed respiration jar of rather small capacity, found that the crayfish, *Cambarus bartoni*, and the nymphs of the dragon-fly, *Anax junius*, have a respiratory rate that is more or less independent of the oxygen of the medium. He showed that both forms are capable of some anerobic metabolism when all of the oxygen has been consumed.

It may well be mentioned here that the conflicting results of various investigators of oxygen tension effects are to no small part *due to the size of the respiration chamber*. In other words, if the experimental animal be placed in a large volume of water, there will be *more total available oxygen* for its use than if it be placed in a small container. That this often erroneously influences the results obtained was demonstrated by Hiestand (1931). Thus when a crayfish is placed in a large volume of water, its respiration will show an independence of oxygen tension over a considerable range; but if it be placed in a jar too small, a "curved line" relationship will appear, since there is not enough available oxygen for a uniform consumption. In such a condition as the latter the interpretation is often that of a dependence of oxygen consumption upon oxygen tension, where as a matter of fact, the animal suffers from asphyxia and does not repay its oxygen debt until removed to media of higher oxygen content. This fact should be carefully considered in all experiments in which oxygen tension is a factor in oxygen consumption.

Material and Methods

Three species of fresh-water molluscs were used. With the exception of the Japanese snail, *Vivipara japonica*, which was obtained from a local dealer in aquarium supplies, the molluscs were obtained from the Wabash River in the vicinity of Lafayette, Indiana. The Wabash in this region is a muddy water, well supplied with branchiate molluscs. The pH of the river was found to be 7.25, or nearly neutral. The molluscs, after removal from the river, were washed carefully with a brush and cloth and placed in laboratory distilled water having a pH value of 5.4. They apparently suffered no harmful effects by being kept in distilled water. In order to determine the metabolic rates in relation to body weight, it became necessary to remove them from their shells, which was done at the conclusion of the experiments. The weights given, therefore, refer to the live weights of the animals exclusive of their shells.

The apparatus used consisted of a wide-mouth jar of 960 ml. capacity, stoppered with a rubber stopper bearing two holes. One hole received a capillary tube to allow inlet of mercury; the other hole admitted a thermometer. No air was entrapped in the bottle during any experiment. Suspended from a hook in the stopper by a thread was a wire screen cage holding the animals. At the side of the jar, midway from top to bottom, was a capillary stop-cock for the withdrawal of water samples for oxygen determination. Clean, washed mercury was admitted by a burette through the capillary tube to replace the water withdrawn for sampling. A more complete and illustrated description of the apparatus can be found in a previous paper by the writer (1931).

Samples of water were withdrawn into special 10 ml. glass-stoppered volumetric flasks for oxygen determination by the micro-Winkler method of Lund (1921). Sodium thiosulphate of N/400 strength was used. Using a 10 ml. sample, each ml. of thiosulphate is equivalent to 2 mgm. of oxygen per liter (2 parts per million), or 1.4 cc. of oxygen per liter. At each withdrawal of sampling water an additional amount (1 or 2 ml.)

of water was removed and allowed to flow over the top of the 10 ml. flask to remove surface water which had come into contact with air during the procedure. It is doubtful that this precaution was necessary because of the short interval of time elapsing during the withdrawal of the sample. Specially prepared micro-pipettes were made to deliver 0.1 ml. of the reagents used in the determination. The micro-Winkler method of oxygen determination has been thoroughly tested by the writer in previous work and found to be as accurate as the ordinary method using a 250 ml. sample of water.

Experiments With Diminishing Oxygen Tension

1. *Vivipara japonica* (Von Martens).—When individuals of this species were placed in the cage and allowed to decrease the oxygen tension by their own oxygen consumption, quite uniform results were obtained. The gastropods remained quiet during the entire test; so the respiratory conditions can be considered basal. Table I and Figure 1 show the results of one experiment. It will be noted that a lapse of 11 hours occurred during which no readings were made. At the end of this period (the following morning) the same procedure was followed until it became apparent that the low point had been reached. The experiment required 34 hours for completion. Had a smaller animal jar been used, a shorter time would have been necessary for the final oxygen tension to be reached. As can be seen from the graph (Fig. 1), oxygen consumption was quite regular until a low tension of 0.52 cc. per liter was reached. During the next hour oxygen consumption was greatly lessened. The experiment was stopped at this point to prevent injury to the snails. Thus the experiment demonstrates that oxygen consumption can continue to a tension less than one-tenth of that of normal saturation of oxygen in water.

TABLE I.

Vivipara japonica: 2 individuals. Weight (without shells) 33.15 gm. Temp. 23° C.

Hours	Water vol. ml.	Thios. ml.	O_2 per L. mgm.	O_2 per L. cc.
0	960	3.95	7.90	5.53
2	948	3.75	7.50	5.25
4	936	3.54	7.08	4.95
6	924	3.30	6.60	4.62
8	912	3.10	6.20	4.34
10	900	2.87	5.74	4.02
12	888	2.60	5.20	3.64
		(lapse of 11 hours)		
23	876	1.64	3.28	2.29
25	864	1.45	2.90	2.03
27	852	1.23	2.46	1.72
29	840	0.97	1.94	1.35
31	828	0.70	1.40	0.98
32	816	0.55	1.10	0.77
33	804	0.37	0.74	0.52
34	792	0.35	0.70	0.49

2. *Utterbackia imbecillis* (Say).—For a comparison with the previous experiment, bivalves of the above species were used, two being placed in the container at the same time. Table II and Figure 1 show the data obtained. It will be seen from these data that oxygen consumption of *Utterbackia* is relatively uniform from normal tensions to approximately 0.70 cc. per liter.

TABLE II.

Utterbackia imbecillis: 2 individuals. Weight (less shells) 48.43 gm. Temp. 23° C.

Hours	Water vol. ml.	Thios. ml.	O_2 per L. mgm.	O_2 per L. cc.
0	960	4.10	8.20	5.74
2	949	3.52	7.04	4.93
4	938	3.08	6.16	4.31
6	927	2.74	5.48	3.84
8	916	2.14	4.28	2.99
10	905	1.76	3.52	2.46
12	894	1.25	2.50	1.75
14	883	0.82	1.64	1.15
15	872	0.64	1.28	0.89
16	861	0.56	1.12	0.78
17	850	0.52	1.04	0.73

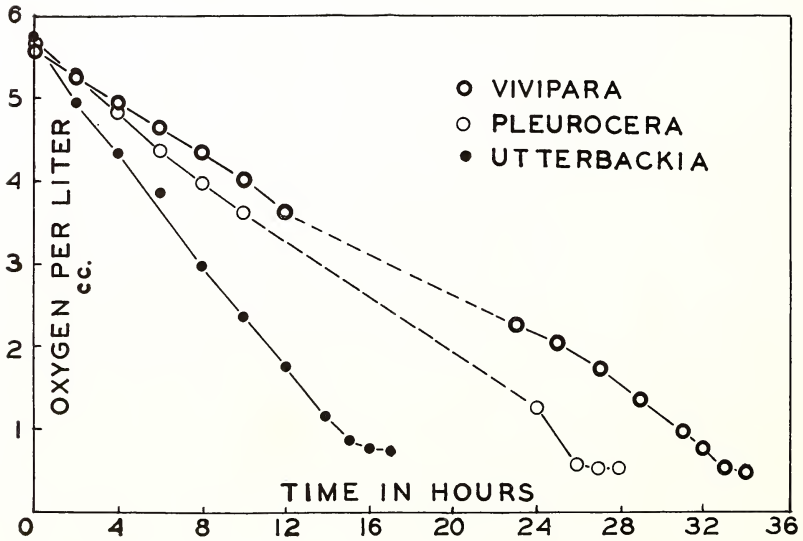

Fig. 1.

3. *Pleurocera undulatum canaliculatum* (Say).—Twenty-eight specimens of this species of *Gastropoda* were used simultaneously. The conditions were similar to those of Table I. During the course of the

experiment, which lasted 28 hours, a period of 13 hours elapsed over night. Here it can be seen that oxygen consumption continued quite regularly down to a concentration of oxygen of approximately 0.50 cc. per liter (about one-tenth that of the start of the experiment). Other experiments, the data of which are not included here, definitely proved that respiration of this species stopped at a tension of 0.50 cc. oxygen per liter.

TABLE III.

Pleurocera undulatum: 28 individuals. Weight (less shells) 10.95 gm. Temp. 23° C.

Hours	Water vol. ml.	Thios. ml.	O_2 per L. mgm.	O_2 per L. cc.
0	960	4.05	8.10	5.67
2	949	3.78	7.56	5.29
4	938	3.44	6.88	4.82
6	927	3.10	6.20	4.34
8	916	2.85	5.70	3.99
10	905	2.58	5.16	3.61
		(lapse of 13 hours)		
24	894	0.88	1.76	1.23
26	883	0.42	0.84	0.58
27	872	0.38	0.76	0.53
28	861	0.38	0.76	0.53

Discussion

These investigations have shown that branchiate molluscs are able to remove oxygen from the surrounding water at a fairly uniform rate from a tension of normal oxygen saturation to levels of relatively low oxygen percentages. The writer has been unable to find evidence of any free-living animal able to withstand such low tensions as the molluscs, unless living under anoxybiotic conditions as *Corethra* and *Chironomus*, as demonstrated by Juday (1908). When we bear in mind that molluscs of these varieties live in streams, the water of which is exposed to atmospheric air, it appears a remarkable fact that they should be able to respire at a uniform rate over a range of oxygen pressures as considerable as these. The fact that oxygen consumption is not proportional to oxygen tension seems to indicate one of two possibilities. Either (1) *the animals use so little oxygen that all pressures above the minimum are greatly in excess of their needs*, or (2) *they are able to regulate their metabolic rate in such a way that they are able to consume proportionally more oxygen at lower tensions than at higher ones.* When one considers the slow rate of metabolism of molluscs as compared with that of other animals, the former explanation appears more plausible than the latter.

In relation to gram-body weight the rate of metabolism is greatest for the genus *Pleurocera*, less for the genus *Utterbackia*, and least for the genus *Vivipara*. Table IV has been compiled from the data of the

preceding experiments. It indicates the rate of metabolism of each species when reduced to the same standard conditions.

To this may be added the metabolic rate of another gastropod which has been recorded in other respiration studies, at same pH,—

TABLE IV.—Standard rate of respiration at pH 5.4
Pleurocera: .016 cc. O_2/gram body wt./hour.
Utterbackia: .008 cc. O_2/gram body wt./hour.
Vivipara: .004 cc. O_2/gram body wt./hour.
Campeloma crassulum (raf.) .009 cc. O_2/gram body wt./hr.

It can be seen from the metabolic rates that the smaller species of molluscs respire at a greater rate than the larger ones, which fact agrees with the comparative rates of other animals in general.

Summary

Each of the three species of molluscs used in this investigation consumed oxygen at a fairly uniform rate until quite low tensions were reached. For the Japanese snail *Vivipara japonica* (Von Martens), oxygen consumption ceased at a concentration of about 0.49 cc. per liter. For the bivalve *Utterbackia imbecillis* (Say), the low point reached was approximately 0.73 cc. per liter. For the gastropod *Pleurocera undulatum canaliculatum* (Say), the lowest tension was about 0.53 cc. per liter. Explanations of the ability of molluscs to respire at very low concentrations of oxygen have been suggested in this paper. The relationship of metabolic rate of four species of molluscs to size have been shown.

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Respiration Studies With Fresh-Water Molluscs:

II. Oxygen Consumption in Relation to Hydrogen-ion Concentration

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Considerable work has been carried on in the investigation of oxygen consumption of aquatic animals, principally with fishes, in relation to the hydrogen-ion concentration of the surrounding water. Hyman (1925) has shown that acidifying the water (lowering of the pH value) by various acids decreases oxygen consumption of *Planaria*. She stated also that there is a tendency toward acceleration of the rate of oxygen consumption with acetic and possibly carbonic acid. She also found that acidification of carbonate-free water had little or no effect upon the rate of oxygen consumption, except when acidity was produced by carbon dioxide. She gives quite a complete summary of the work up to the time of her investigation. It seems, that in the great majority of cases reported, increased acidity of the water retards oxidation.

Hall (1931) has stated that an increase in hydrogen-ions inhibits oxygen consumption of the puffer fish and that carbon dioxide causes a more pronounced effect than an addition of hydrochloric acid at the same pH.

One of us (1931) using dragon-fly nymphs found an increase in oxygen consumption when the pH of the water was lowered, either by the addition of hydrochloric acid or carbon dioxide. The results of the present work with molluscs are in agreement with those obtained with dragon-fly nymphs. Why there should be these exceptions to the general rule cannot be explained here but will require further investigation. It might possibly be thought that a decreased pH, brought about either by an addition of acid or increase in carbon dioxide, may act as a respiratory stimulus, as is true of warm-blooded vertebrates. To this should be added the more recent work of Johnson (1936) who observed an acceleration of the rate of the respiratory movements of *Squilla mantis*, *Pandalus borealis*, *Cirolana borealis*, and *Idotea neglecta*, in media either containing an excess of carbon dioxide or lacking in oxygen. Whether or not more oxygen was consumed by these crustaceans was not determined, but their increased respiratory activity indicates an attempt in that direction.

Material and Methods

The two species of water-breathing gastropods, *Campeloma crassulum* (Raf.) and *Pleurocera undulatum canaliculatum* (Say), were used. Both of these were obtained from the Wabash River in the vicinity of Lafayette, Indiana. Being small molluscs, groups of them were used simultaneously in the determinations. The apparatus and methods of

gas analysis used were identical to those described in a previous paper appearing in this journal (Hiestand, 1937). The animals were placed in distilled water, the pH of which was varied by the addition of hydrochloric acid or sodium hydroxide, and were allowed to remain for periods of eight hours (one for a period of ten hours). The oxygen tension of the water at the start of each experiment was not exactly the same but nearly so. It was found in other investigations that even when the same stock water was used each time, the oxygen tension was not always the same. This is not unusual when one considers that slight temperature variations occur upon standing of the water; consequently the oxygen dissolved in the stock water will likewise vary. After each experiment the snails were removed from the animal jar and returned to distilled water. After the experiments were completed, the snails were weighed, killed, and removed from the shells. The shells were then weighed separately and the live weight of the snails (less shells) determined.

1. **Experiments with Campeloma.**—Twenty individuals with a weight (less shells) of 19.97 gm. were placed in the animal cage and the latter suspended in laboratory distilled water having a pH value of 5.4. Determinations of oxygen (cc. per liter) were made at intervals of two hours for a ten hour period. A constant temperature of 23° C. was maintained through this and the following experiments. The results are shown by Table I and Figure 1. Following this a second trial was run under as nearly as possible the same conditions. The same stock water as before was used, however, with slightly more (0.08 cc. per liter) oxygen than before. This trial was conducted for an eight hour period as were the following two trials. The results are given in Table II and Figure 1.

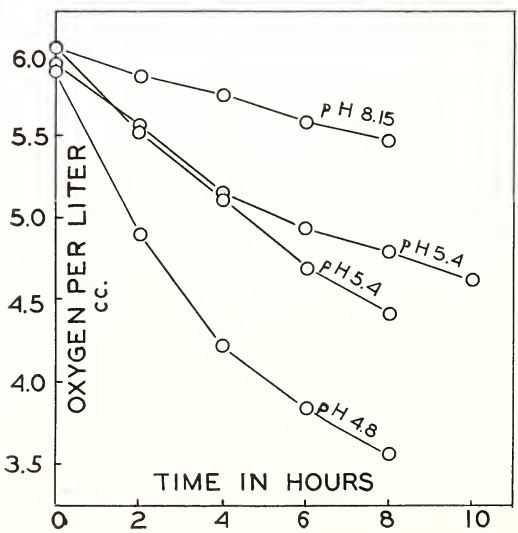

Fig. 1.

TABLE I.

Campeloma crassulum: 20 specimens. Wt. 19.97 gm. pH. 5.4

Hours	Water vol. ml.	Thios. ml.	O_2 per L. mgm.	O_2 per L. cc.
0	960	4.24	8.48	5.94
2	949	3.98	7.96	5.57
4	938	3.68	7.36	5.15
6	927	3.52	7.04	4.93
8	916	3.42	6.84	4.79
10	905	3.30	6.60	4.62

TABLE II.—Same conditions as Table I. pH 5.4

Hours	Water vol. ml.	Thios. ml.	O_2 per L. mgm.	O_2 per L. cc.
0	960	4.30	8.60	6.02
2	949	3.95	7.90	5.53
4	938	3.65	7.30	5.11
6	927	3.35	6.70	4.69
8	916	3.15	6.30	4.41

After these two determinations were made at a pH of 5.4, the hydrogen-ion concentration of the stock water was decreased by addition of three drops of a saturated solution of sodium hydroxide until a pH of 8.15 was reached. The results of the increased pH are shown in Table III and Figure 1.

TABLE III.—Same conditions as preceding tables except pH 8.15

Hours	Water vol. ml.	Thios. ml.	O_2 per L. mgm.	O_2 per L. cc.
0	960	4.30	8.60	6.02
2	949	4.18	8.36	5.85
4	938	4.10	8.20	5.74
6	927	3.98	7.96	5.57
8	916	3.90	7.80	5.46

It then seemed desirable to determine the effects of raising the hydrogen-ion concentration. One drop of concentrated hydrochloric acid was added to the stock water lowering the pH to 4.8. Otherwise the conditions were the same as previously. The results are shown in Table IV and Figure 1.

TABLE IV.—Same conditions as preceding tables except pH 4.8

Hours	Water vol. ml.	Thios. ml.	O_2 per L. mgm.	O_2 per L. cc.
0	960	4.20	8.40	5.88
2	949	3.50	7.00	4.90
4	938	3.02	6.04	4.23
6	927	2.75	5.50	3.85
8	916	2.55	5.10	3.57

Discussion

The foregoing experiments definitely show a marked effect of the hydrogen-ion concentration of the water on the rate of oxygen consumption of the snail, *Campeloma*. An inverse relationship exists between pH and oxygen intake. So marked is the effect of the hydrogen-ion concentration that (at the end of an eight hour period) the oxygen consumed at a pH of 4.8 was approximately 50% more than at a pH of 5.4, and about 300% more than at a pH of 8.15. Whether the consumption of oxygen in molluscs behaves as a simple diffusion process cannot be stated until more information is available. Since increased acidity of the surrounding water causes an increase in oxygen used, one might look for a more complicated explanation than diffusion alone. In general, increasing the acidity of the medium tends to inhibit cellular activity so one would expect to find a similar effect with the respiration of molluscs unless a separate mechanism exists that responds to an increased hydrogen-ion concentration such as a respiratory center.

2. Experiments with Pleurocera.—These gastropods, being smaller than the former, were used in larger numbers. A group of 30 snails was used for the following tests. The weight without shells was found to be 10.22 gm. Three determinations at different hydrogen-ion concentrations were made. Although the results obtained were not as marked as with *Campeloma*, nevertheless comparable results were obtained. The experiment was started at a pH of 5.4, using the same stock water as previously. Determinations were made at two hour periods until eight hours had elapsed . The results of the first trial are shown in Table V and Figure 2. At the end of this eight hour period the oxygen concentration of the water had been reduced to 4.65 cc. per liter.

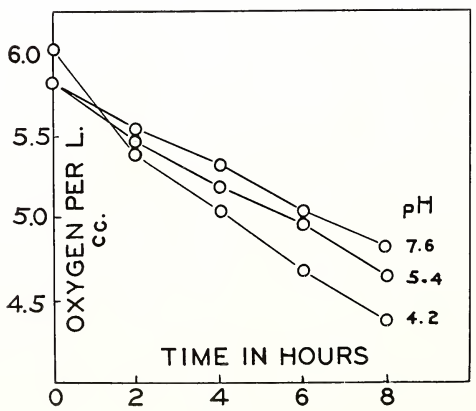

Fig. 2.

TABLE V.—*Pleurocera undulatum:* 30 individuals Wt. 10.22 gm. pH 5.4

Hours	Water vol. ml.	Thios. ml	O_2 per L. mgm	O_2 per L. cc
0	960	4.15	8.30	5.81
2	949	3.90	7.80	5.46
4	938	3.70	7.40	5.18
6	927	3.55	7.10	4.97
8	916	3.32	6.64	4.65

Following this trial the water was acidulated with concentrated hydrochloric acid, lowering the pH to 4.2. At the end of this trial the oxygen had been reduced to 4.37 cc. per liter, which indicates a greater amount used at a pH of 4.2 than at 5.4. The results are incorporated in Table VI and Figure 2.

TABLE VI.—Same conditions as Table V except at pH 4.2

Hours	Water vol. ml.	Thios. ml.	O_2 per L. mgm.	O_2 per L. cc.
0	960	4.30	8.60	6.02
2	949	3.85	7.70	5.39
4	938	3.60	7.20	5.04
6	927	3.34	6.68	4.68
8	916	3.12	6.24	4.37

Following this experiment the same individuals were placed in water with a pH of 7.6, prepared by adding sodium hydroxide to the stock water. The results are given in Table VII and Figure 2. It can be seen that at this higher pH oxygen consumption is less than at the other levels.

TABLE VII.—Same conditions as Tables V and VI except at pH 7.6

Hours	Water vol. ml.	Thios. ml.	O_2 per L. mgm.	O_2 per L. cc.
0	960	4.16	8.32	5.82
2	949	3.89	7.98	5.54
4	938	3.80	7.60	5.32
6	927	3.60	7.20	5.04
8	916	3.44	6.88	4.82

Discussion

Even though the variations in oxygen consumption at different pH values of the water of this series of experiments are less significant

than those with the snail, *Campeloma*, nevertheless, they are in the same direction; that is to say, at higher concentrations of hydrogen-ions the respiration becomes augmented.

Since the original experiments were performed, other individuals of the same species were used as checks and were found to behave in the same manner in respect to the hydrogen-ion concentration of the water. Also *Vivipara japonica* was tried at different pH levels. Although this species does not respire at as uniform rates, even at the same pH, as the above snails, nevertheless there is a definite trend in the same direction. *Vivipara* is not as reliable an experimental animal as it often remains retracted in its shell for periods of several hours, at which time the oxygen consumption may be practically negligible. After extension of the foot, however, the oxygen consumption progresses at a faster rate so that in a period of six or more hours a fairly definite reading of oxygen consumption can be taken.

Summary

The rate of oxygen consumption of the gastropod molluscs, *Campeloma crassulum, Pleurocera undulatum,* and *Vivipara japonica* is increased when the hydrogen-ion concentration of the surrounding water is increased. The opposite condition is also true if the hydrogen-ions are decreased. With *Campeloma* the effect is very marked, with *Pleurocera* less so. The respiration of *Vivipara japonica* is much less regular than that of the two preceding species of snails.

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Some Observations on the Reproductive Cycle of a Common Land Snail, Vallonia Pulchella. Influence of Environmental Factors[1]

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The present paper is preliminary to a more comprehensive study of the origin and development of the germ cells in *Vallonia pulchella* Müll. During the progress of the work, the animals were brought into the laboratory in considerable numbers, and there was ample opportunity for observations of egg-laying, hatching, and development, and, in connection with these, of the physiological effects of environmental factors such as cold and desiccation.

General Description of Material

Vallonia pulchella is a small land snail of wide distribution, with a smooth helicoid shell averaging a little more than 2.0 mm. in diameter. It may or may not be found associated with the ribbed species, *V. costata*. Large populations are found typically among grass roots at the edges of lawns next to a stone or cement walk or wall. They were collected from such typical locations in Ann Arbor, Michigan, and other places, where they were found at times so thickly congregated as to be crowded against one another. They were also collected from under old boards and pieces of brick and cement around dwellings and lumber yards. V. Sterki (1910) refers to the fact that, while deforestation, drainage, etc., have tended to reduce many species of snails, in the case of *Vallonia*, which is not a forest species but found in more open country, urban conditions have favored its increase, so that "a single well-sprinkled house lawn may be populated by more individuals than were in 1000 acres of original forest." Sporadic appearances of *V. pulchella* have been reported by Clapp (1897) in Pittsburgh, where they appeared literally in millions on his front walk after a rain, and (1901) in similar numbers near a stone wall on the estate of a friend about six miles out of town, and again by Stearns (1902) in Los Angeles.

During the present study, adults were collected at all seasons of the year, and eggs and juveniles during the months of May, June, July, and August, and juveniles also in September. During August a number of mixed collections of eggs, juveniles of various sizes, and adults were made along one of the walks on the Butler University Campus at Indianapolis. In the Ann Arbor locations, large aggregations of adults were found in the late fall and early spring, and considerable numbers in the winter, but juveniles were not noted among them.

The eggs, as observed both in the natural habitats and in the laboratory, are laid singly. They are spherical in form, a little more than 0.5 mm. in diameter, and quite fill up the aperture of the shell as

[1] Contribution from the Department of Zoölogy, University of Michigan.

they are extruded. They are covered with a pure white calcareous shell and are visible through the shell of the parent animal some time before being laid. When freshly laid, they appear somewhat translucent and have a pearly lustre but become darker and more opaque with age. They are affixed by mucous material to the under surfaces of bits of wood or dead leaves, or to grass roots or moss if present, or they may be inserted into the interstices of loose clumps of soil. These locations reflect the habits of the animals, which apparently do not burrow to any great extent but seek cover under surface objects. Even in winter they are found at the surface beneath the snow in an inactive condition.

Collecting and Culture Methods

Collections of individuals from one of the typical locations in Ann Arbor were brought in from time to time during the late fall, winter, and early spring. At the same time this typical site was watched for the appearance of eggs. The animals were inactive when brought in but soon became active under the usual laboratory conditions. The collections were kept in covered finger bowls with a little soil and a bit of dead leaf or decaying wood brought along from the natural location. A little fresh lettuce was also supplied occasionally. These laboratory cultures were kept moist by sprinkling every day or two, care being taken to avoid saturation, since under too moist conditions the animals would crawl up on the sides and covers of the dishes and remain inactive.

Eggs appeared freely in these mass cultures in a short time, usually after not more than a week. They were not found in any abundance in the out-of-door locations until May 21.

Production of Eggs by Isolated Individuals

In order to make a more detailed study of egg laying, the number of eggs produced by individual animals, and the time intervals involved, eighteen individuals from a collection made on April 24 were isolated in separate stender dishes with food, moisture, and temperature conditions as described above. These cultures were maintained over a period of several months, during which time records were kept of the number of eggs produced by each individual. Five of these individual records, quite typical of the group as a whole, are given below in Table I. It did not prove feasible to make daily records during the entire period, but this was done part of the time. Portions of the table are blocked off calling attention to the tendency for egg laying to occur at approximately 24-hour intervals when conditions were favorable. However, inspection of the table reveals that the interval may frequently be less. One exact record (not shown) was obtained of a 23-hour interval and another of 14 hours and 35 minutes.

It will be recalled that in the out-of-door location eggs were not found in any abundance until about May 21. By that time the eighteen laboratory individuals had laid a total of 322 eggs.

For ten of the eighteen individuals, records like those above were obtained extending through May, June, and July. The average number of eggs produced during this period was 53, the individual records varying from 30 to 69. Egg laying continued into August, but these records are not included.

TABLE I.—Individual Records of Egg-laying

Date of Record	No. Eggs Found					Date of Record	No. Eggs Found				Date of Record	No. Eggs Found			
	D.	E.	J.	K.	N.		D.	J.	K.	N.		D.	J.	K.	N.
April 27	1				2	May 22	3	1	1		July 1	1		1	
April 28			2	1	1	May 23	1	1	1	2	July 3	1	1		2
April 29		1	1		1	May 28	8		3	2	July 4		1	1	
April 30		1			1	June 4	9	8		6	July 6	1	3	1	2
May 1	3	1	3	3	2	June 5	1	1		2	July 7	1	1		1
May 2	1	1			1	June 6	1	2		2	July 8		1		
May 3	1	1	2	1	3	June 14		2			July 9	1	1	1	1
May 4	1	1			1	June 15	9			2	July 10	1	1	1	1
May 5			2			June 22		6	1		July 11	1		1	1
May 7	2	1	1	1	3	June 23				1	July 12		1	1	
May 10	5	2	2	4	5	June 25			2		July 13	1		1	1
May 11		1	1	2		June 26				1	July 30	1		1	1
May 12					4	June 27	1	1		1					
May 15	4		4			June 28	1								
May 19	5	3			3	June 29	1	3		1					

Observations of Growth and Development

The embryo, when dissected out of a recently laid egg, consists of a small delicate ball of vacuolated cells a mere fraction the size of the entire egg. But at the time of hatching, which occurs in the laboratory in about twelve days, the young animal has filled up the egg shell and has attained its characteristic form and completed a whorl of its body shell. The little animal is delicately transparent, and the beating of the heart can be easily observed. It moves about actively after hatching.

In order to test whether individuals reared in isolation would reproduce and to get an idea of the rate of growth of the juveniles and the time required to reach sexual maturity, about two dozen juveniles produced in the laboratory by the group of eighteen individuals mentioned above were reared in separate stender dishes from the time of hatching. For 15 of these it was possible to obtain growth records at intervals of about a week up to and including the formation of the peristome and the beginning of reproduction. Samples of these records are given in Table II. As shown by the table, growth was fairly steady, the average gain in width being about 0.2 mm. per week. A little more rapid gains are shown at times when fresh food materials were supplied. In a number of instances when culture dishes were allowed to become dry, the animals became inactive and failed to gain, but they made normal gains after favorable conditions were restored.

TABLE II—Growth Records of Isolated Juveniles

Date	B-1	D-6	E-4	F-1	Remarks
May 12	.....	.....	.....	0.7 mm.	
May 13	0.6 mm.	.....	.....	.....	Just hatched.
May 18	.....	0.7 mm.	.....	.....	
May 20	0.8 mm.	.....	.....	1.0 mm.	
May 21	.....	.....	0.7 mm.	.....	
May 25	.....	0.9 mm.	.....	.....	
May 26	.....	.....	.....	1.2 mm.	
May 27	1.1 mm.	.....	.....	.....	
May 28	.....	.....	0.9 mm.	.....	
June 2	1.2 mm.	1.1 mm.	1.1 mm.	1.7 mm.	New substrate
June 10	1.6 mm.	1.7 mm.	1.6 mm.	1.8 mm.	
June 24	.....	.....	.....	.....	New substrate
June 25	1.7 mm.	2.1 mm.	1.7 mm.	1.9 mm.	Peristome formed in D-6 and F-1.
June 29	.....	1st and 2nd eggs	.....	1st egg	
July 1	.....	3rd egg	.....	2nd egg	
July 2	1.9 mm.	.....	2.0 mm.	.....	Peristome not yet formed in B-1. Present in E-4.
July 6	.....	4th egg	.....	3rd egg	
July 9	2.1 mm.	5th egg	1st egg	4th egg	Peristome formed in B-1.
July 15	.....	6th, 7th, 8th eggs	.....	.....	
July 17	1st and 2nd eggs	.....	2nd, 3rd, 4th eggs	.....	
July 19	3rd egg	9th egg	5th and 6th eggs	.....	

On the average in this group, egg-laying began in a week or less after the formation of the peristome was completed. The average time between hatching and maturity for the fifteen specimens was 59 days, and the average diameter at the time of first oviposition was 2.0 mm. These figures must be regarded as approximate, since it was not always possible to record exact dates of either egg-laying or hatching.

Not only did the above group of juveniles reared in isolation lay eggs as shown in the table, but some of these eggs placed in individual stender dishes hatched in the normal manner, giving rise to juveniles of the third generation, which in turn laid viable eggs of the fourth generation. Thus it was possible to construct a calendar covering portions of four generations as in Table III.

TABLE III.—Record of Four Generations of *Vallonia pulchella* Müll.

Line	Total days	Parent	When mature	Egg	Date of laying	Hatched	Generation	Days
I	146	D	Coll. 4/24	D-6	5/6	5/17-18	2	53
		D-6	6/29	D-6-b	7/1	7/12	3	62
		D-6-b	8/30-9/1	D-6-b-1	8/30-9/1	9/13-19	4	.....
II	147	F	Coll. 4/24	F-1	5/1	5/12	2	59
		F-1	6/29	F-1-a	6/29	7/11	3	62
		F-1-a	8/30-9/1	F-1-a-1	8/30-9/1	9/13-19	4	.....

Environmental Factors Affecting Egg-laying, Development, and Survival

The fact that egg-laying took place in the laboratory in winter and early spring, but not until considerably later out of doors, suggested

that the higher and more uniform temperature and moisture in the laboratory favored egg-laying, since the substrate for the laboratory specimens was essentially like that of the natural habitat. As shown in Table I, animals collected April 24 were prepared to lay eggs in a short time if suitable conditions were provided. To test the inhibiting effects of low temperature and desiccation, a part of this collection was divided into three experimental groups; one group was placed in individual stender dishes in a refrigerator at temperatures of 12°-15° C., the second group was placed in dry vials with cotton stoppers, at laboratory temperatures of 21° to 22° C., and the third group in dry vials in the refrigerator. At weekly intervals one individual was removed from each of the above groups and restored to favorable conditions of temperature and moisture and the time noted when egg-laying began. The last two groups were necessarily deprived of food as well as moisture during the experimental periods since the animals cannot feed while in the inactive aestivating condition. A few specimens were also kept for periods of one to three weeks in stender dishes provided with moist filter paper but no soil or food.

Besides these adult groups, a few groups of eggs and juveniles were tested for their resistance to varying periods of cold and dryness.

The inhibiting effects of low temperatures and desiccation and the recovery from these effects are shown in Tables IV-VII. The animals in the first group were not immobilized by the refrigerator temperatures used but were often found slightly active and feeding when the dishes were taken out for inspection. Nor did refrigeration completely inhibit egg-laying, as shown in Table IV. However, only 13 eggs were recorded laid at refrigerator temperature by the group as a whole over a period of about three months, as compared to hundreds laid by the group represented by Table I, which was considered as a control group. No record was obtained of the hatching of any eggs in the refrigerator.

In the case of the animals kept in dry vials, no egg-laying took place during the inactive aestivating period, but as shown by Tables V and VI, oviposition began in a few days after favorable conditions of moisture, temperature, and food were restored. The recovery interval

TABLE IV.—Effects of Refrigeration on Egg-laying

Individuals	Refrigeration Period	Restored to Lab. Temp.	Egg-laying Begun at Normal Rate	Recovery Interval
AA	7 days	May 1	May 2	1 day
AB	16 days	May 10	May 12	2 days
AD	22 days	May 16	May 17	1 day
AF	30 days	May 24	May 28	4 days
AG*	40 days	June 3	June 6	3 days
AH	45 days	June 8	Inactive after June 28	No eggs
AI	68 days	June 28	June 29	1 day
AP*	81 days	July 11	July 15-18	4-7 days
AS*	89 days	July 19	July 20	1 day
AT*	96 days	July 26	July 27	1 day
AX*	103 days	Aug. 2	Aug. 3	1 day

*Laid 1-3 eggs in refrigerator before restoration to laboratory temperature.

TABLE V.—Effects of Desiccation on Egg-laying

Individuals	Aestivation Period	Moisture etc. Restored	Egg-laying Begun	Recovery Interval
BA	7 days	May 1	May 6	5 days
BB	16 days	May 10	May 12	2 days
BD	22 days	May 16	Became inactive	No Record
BF	30 days	May 24	May 27	3 days
BG	40 days	June 3	June 6	3 days
BH	45 days	June 8	June 12	4 days
BI	68 days	June 28	July 7*	9 days*
BJ	75 days	July 5	July 8	3 days
BK	81 days	July 11	July 17	6 days
BL	89 days	July 19	July 23	4 days
BM	96 days	July 26	Became inactive	No record
BN	103 days	Aug. 2	Became inactive	No record
BO	110 days	Aug. 9	Became inactive	No record
BQ	117 days	Aug. 16	Aug. 21	5 days

*Observation was delayed in this instance. The interval was probably less.

TABLE VI.—Effects of Combined Refrigeration and Desiccation on Egg-laying

Individuals	Period of Refrigeration & Aestivation	Restored to Moisture Lab. Temp. etc.	Egg-laying Begun	Recovery Interval
CA	7 days	May 1	May 7	6 days
CB	16 days	May 10	May 15	5 days
CD	22 days	May 16	May 19	3 days
CF	30 days	May 24	May 27	3 days
CG	40 days	June 3	June 6	3 days
CH	45 days	June 8	Became inactive	No record
CI	68 days	June 28	Record uncertain	
CJ	75 days	July 5	Became inactive	No record
CM	81 days	July 11	July 18	7 days
CN	89 days	July 19	July 26	8 days
CO	96 days	July 26	Aug. 3	8 days
CP	103 days	Aug. 2	Became inactive	No record
CQ	110 days	Aug. 9	Aug. 12-15	3-6 days

TABLE VII.—Environmental Effects on Eggs and Juveniles

A. Effects of Refrigeration

Eggs		Hatching	Exper. Period	Juveniles	
Exper. Period	No. Individuals			No. Individuals	Recovery
15 days	Group 1—14	+	8 days	5	+
	Group 2—10	—	7 days	3	+
7 days	22	+	2 days	8	+

B. Effects of Desiccation

15 days	14	—	61 days	10	—
7 days	15	—	14 days	7 small	— One Doubtful
2 days	7	—		6 larger	+
			8 days	3	+
			7 days	5	+
			2 days	8	+

C. Effects of Refrigeration + Desiccation

15 days	12	—	8 days	5	—
8 days	7	—	7 days	3	—
7 days	14	—	2 days	5 small	—
2 days	5	—		3 larger	?

apparently does not differ greatly whether the experimental period has been long or short, and the animals recover about as well from a combination of refrigeration and desiccation as from desiccation alone. In part, the importance of the recovery interval seems to be to permit a period of feeding. The few animals provided with moisture but no food or soil did not deposit any eggs under those conditions but in several cases laid eggs at the normal rate when food and soil were added.

In Table VII, the symbols + and — indicate whether any eggs in a given group hatched or whether any juveniles recovered activity after experimental treatment. The eggs proved fragile and difficult to handle after drying, and there was some breakage, loss of specimens, and difficulty in making exact observations in each case. Because of the limited nature of the experiments, the results should perhaps be regarded as merely suggestive; but they indicate that the eggs are very susceptible to desiccation when exposed. It will be recalled that in nature they are deposited in protected places where moisture is retained and that the juveniles are not hatched until the body shell has developed to take over the protection hitherto provided by the egg shell. The juveniles are apparently more resistant to desiccation than the eggs but less so than the adults. Younger juveniles are less resistant than older ones.

In the case of eggs which hatched after undergoing a period of refrigeration, it should be mentioned that hatching was delayed for a period approximately equal to the refrigeration period.

Discussion

The above experiments indicate that reproduction in *Vallonia pulchella* may involve parthenogenetic development or some type of self-fertilization, since it was found that individuals reared in isolation produced eggs which were viable and hatched in the normal manner for several successive generations. Literature records several instances of a similar kind among snails. Crabb (1927) found that, in the case of *Lymnaea stagnalis*, "individuals raised from isolated eggs and reared in strict isolation reproduce as abundantly as do those in mass cultures" and quotes Colton (1922) as having recorded self-fertilization in *L. columella* for 47 generations.

Self-fertilization has been suggested by Boycott (1917) and Steenburg (1918) for *Acanthinula aculeata*, a species believed to be closely related to *Vallonia*, since they found the distal portions of the male ducts absent in many cases. Boycott, in discussing this phenomenon, inclines to the view that the aphallic state is due to the simplification of structure which is necessarily associated with diminution in absolute size.

Watson (1919) dissected 98 specimens of *Vallonia*, including some *V. costata*, some *V. pulchella*, and some *V. excentrica* collected in both spring and fall, and found male organs present only in three specimens of *V. costata*. In the remaining 95 they were entirely absent.

Reproduction by isolated *Vallonia* as found in the present study is in harmony with these anatomical observations. It is hoped in the further study to correlate these evidences with histological and cytological findings.

As far as the present study goes, it does not give evidence of any very definite periodicity or anything very complicated about the reproductive cycle but indicates rather that egg-laying may take place whenever the animal is in a good state of nutrition and external conditions are favorable. Egg production is somewhat limited at best because of the large size of the eggs in proportion to the size of the animal, which necessitates their being laid singly at a rather slow rate. Temperature and moisture conditions impose further limitations. It would be a disadvantage if eggs were laid under dry conditions, as they are very susceptible to desiccation, or during cold weather, because the retarding effect on hatching would prolong their exposure to other hazards.

Along with the inhibiting effects of these factors, we have noted the ability of the animals to recover from them quickly. We have observed that specimens collected in the fall and winter began laying eggs after a short time in the laboratory. Individuals collected in the spring, ready to lay eggs in a short time, were retarded experimentally for periods of one week to three months by cold and dry conditions, but egg-laying began in a few days when favorable conditions were provided. This opportunism in egg-laying appears to be of considerable adaptive significance in enabling the animals to take advantage of favorable conditions when they occur.

It is hoped to make studies of other factors such as nutrition as they affect egg-laying. The fact that the animals begin to lay eggs usually in less than a week after the peristome is formed, i. e., when the shell is completed (Table II), might suggest that mineral materials taken in with the food, used hitherto for adding to the shell, at this time become available for the formation of the egg shells.

We can see from these studies how reproduction in *Vallonia* would be favored by urban conditions as emphasized by Sterki, previously quoted. Egg-laying could take place during a much greater part of the summer season on a regularly sprinkled lawn than in regions favored only by natural rainfall. We can interpret the sporadic appearances recorded by Clapp and Stearns and the large aggregations found during the present study in a similar way. It has been suggested that these large aggregations may be due to migrations inward to some protected favorable location from surrounding territory, but it seems more likely that they may represent the piling up of populations under somewhat artificially favorable conditions.

I take this opportunity to make acknowledgment to Dr. Peter O. Okkelberg for suggesting the problem and directing the work. I wish also to thank Dr. Ray C. Friesner of Butler University for working accommodations in the Botany Department during a part of the study and Dr. John E. Potzger of the same department for helpful suggestions given during that time. For assistance in collecting and identification and other favors, I am indebted to Mr. Calvin Goodrich and Dr. Allan Archer of the University of Michigan Museum of Zoology, and also to other members of the Zoology and Museum staffs.

Summary

1. Specimens of *Vallonia pulchella* Müll. brought into the laboratory in fall, winter, and early spring began laying eggs in from a few

days to a week or two. Eggs were not found in any considerable numbers until the middle of May. They were collected from time to time throughout the summer.

2. The eggs are laid singly, and under optimum conditions in the laboratory one egg is laid each day and sometimes more.

3. Hatching occurs in the laboratory in about 12 days. The juveniles at the time of hatching are well-developed and quite active. One whorl of the shell is completed, and they measure about 0.6 mm. in diameter.

4. Juveniles reared in isolation from the egg showed a steady growth under favorable conditions of about 0.2 mm. per week (diameter of the shell) and reached adult size in an average of 59 days. They began laying eggs usually in less than a week after the formation of the peristome. The average diameter at this time was 2.0 mm., the normal adult size.

5. Individuals reared in isolation for several succeeding generations reproduced.

6. Refrigeration and desiccation have retarding and inhibiting effects on egg-laying and development, but the animals recover rapidly from these effects. Refrigeration is less inhibiting than desiccation. The eggs are very sensitive to desiccating influences. In nature they are deposited in protected places. Juveniles are less susceptible to desiccation than the eggs. With age the juveniles become progressively more resistant to unfavorable conditions.

7. In general, this study shows that *Vallonia* is able to reproduce without cross-fertilization, suggesting either parthenogenesis or some form of self-fertilization, and that the reproductive cycle is strongly influenced by environmental factors.

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Staining Methods for General Use in Studying Protozoa

W. P. Allyn, Indiana State Teachers College

The study of Protozoa has presented some difficulties in the past because of the necessary time and skill involved in the preparation of stained mounts and of certain injuries suffered by the organisms during the fixing and staining processes. It is believed that the suggestions offered here will prove helpful to those interested in a general and more or less elementary phase of this study, the observation of both the external and internal structures of the organisms, including the nuclear patterns.

Certain problems were encountered in an attempt to devise simple, yet effective, combined fixing and staining techniques for general use. It was found that the different species of Protozoa do not respond alike in all cases to the same fixing and staining procedures. Moreover, in some cases members of the same species show noticeable variations. The differences in staining reactions seem to be attributed not only to such factors as the quantities and compositions of inclusions present but also to the age and general physiological state of the species at the time of staining.

Combined Fixative and Differential Stain for Temporany Mounts: 10cc. glycerine; 2cc. phenol (crystals reduced to a liquid by heat); 2 cc. glacial acetic acid; 100 milligrams methyl green; 1 milligram crystal violet; 100 cc. water. Note: A stock solution of crystal violet is prepared by dissolving 100 milligrams of crystal violet in 10 cc. of alcohol and diluting it to 100 cc. with water. Hence 1 cc. of stock solution contains 1 milligram of the dye. Also 2-4 cc. of 40% formaldehyde improves the above reagent for many protozoa, excluding the Hypotrichida.

The combined fixative and differential stain is introduced directly into a living suspension of the organisms on a microslide. An amount of stain approximately equal to that of the suspension of organisms was found to give satisfactory results. It requires some 10 minutes or longer for the Protozoa to absorb the stain, and the process may be observed conveniently under the microscope. The methyl green exhibits an affinity for the nuclear materials, while the crystal violet is absorbed in the main by the cytoplasm of the animal, thus giving a blue-green cast to the nucleus and a faint violet hue to the endoplasm.

It is noted that if an adequate amount of the staining reagent is used, the mount may be permitted to air-dry at room temperature for several days without any appreciable injury to the organisms. Since the glycerine contained in the stain is not volatile at ordinary temperatures, it remains incorporated in and around the specimens and acts as a preservative. After several days standing preparations have been rejuvenated with a drop of water, or preferably with a drop of the original reagent (without the dye), and the organisms were found to be preserved in excellent condition.

It is observed also that the density of the dye in the organisms can be controlled within certain limits. If it be desirable to intensify the dye, more of the original reagent may be added from time to time; but if too much of the dye has been absorbed and the organisms are becoming opaque, a drop of water, or preferably a drop of the original reagent without the methyl green and crystal violet, will tend to clear the specimen and render the internal structures visible. If further dilution is desired, the slide may be tilted slightly, the excess reagent floated off or absorbed by a filter paper, and more of the diluting reagent added until a dye-density best suited for the species under observation is attained.

If the organisms are laden with food vacuoles or other inclusions which absorb sufficient dye to obscure the nuclear patterns, it may be found expedient to omit the crystal violet entirely from the original staining reagent.

Satisfactory mounts of many of the common forms can be obtained with the above procedure. The various species of Amoebae, also *Paramecium caudatum, aurelia,* and *bursaria, Euplotes patella, Stylonychia mytilis* and *pustulata, Gastrostyla steinii,* and other representatives of the Sarcodina, Infusoria, and Mastigophora seem to respond in a very favorable manner.

Combined Fixative and Flagella Stain for Temporary Mounts: 10 cc. glycerine; 2 cc. glacial acetic acid; 5 cc. phenol (crystals reduced to a liquid by heat); 25 milligrams crystal violet; 100 cc. water.

The combined fixative and flagella stain is introduced also directly into a suspension of the organisms on a slide in a similar manner to that just described for the differential stain. The dye is usually absorbed within a few minutes, and the flagella, cilia, or cirri become rather easily discernible.

The reagent submitted here is a modification of a formula presented by Noland[1]. It is believed, however, that the immediate preparation possesses some advantages over that described by Noland. The Noland reagent, when introduced into a suspension of the organisms, was observed to react rather violently with the latter, the organisms were swept about in the medium by certain vortical currents set in motion, and many of the flagella, hardened by the formaldehyde, were broken off. On the other hand, by omitting the formaldehyde of the Noland reagent and adding 2% glacial acetic acid and also by decreasing the amount of phenol to 5% and increasing the glycerine content as indicated above, no appreciable damage to the flagella is produced during the preparation of mounts.

A Fixative for Permanent Mounts of Amoeba: 2 cc. glacial acetic acid; 2 to 4 cc. formalin (40% formaldehyde); 10 cc. glycerine; 100 cc. distilled water.

The reagent just described proved very satisfactory for killing and fixing Amoebae on slides preparatory to staining with iron-hematoxylin in the preparation of permanent mounts.

[1] Noland, Lowell E., 1928. A combined fiixative and stain for demonstrating flagella and cilia in temporary mounts, Science. 67:535.

A suspension of the Amoebae on a slide is observed with the low-power objective in order to determine when the organisms have the pseudopodia extended and in contact with the slide. At the proper time, the reagent, equal in quantity at least to that of the suspension of organisms, is added. After some three to five minutes have elapsed, the fixative and killing solution may be drained off gently by tilting the slide. Then by adding more reagent and repeating the process, much of the debris, which would otherwise obscure the Amoeba, can be floated off.

Amoeba, treated as described, remain intact and fixed sufficiently to the slide to endure rather rigorous treatment during the staining process. Following fixation, the preparations may be plunged immediately into 2% iron alum, then to hematoxylin, differentiated in ½ to 1% iron alum, and carried up with a very low casualty through the alcohols and xylols into balsam (Fig. 1).

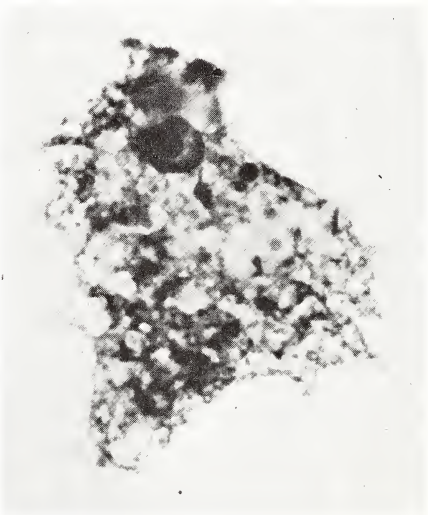

Fig. 1. Amoeba killed and fixed by the method for permanent mounts; stain, iron haematoxylin. x850.

It is well recognized that the suggestions set forth here are in need of many revisions and much refinement, but it is hoped that a preliminary step has been made at least in developing simpler and more convenient methods for studying these minute forms of animal life.

JUNIOR ACADEMY OF SCIENCE

Officers for 1937:

President: GEORGE HOFFER, West Lafayette High School.
Vice-President: DAVID WILLIAMS, Valparaiso.
Secretary: BARBARA BADGER, Shortridge, Indianapolis.
Treasurer: MARY TUDOR, Marion.

PROGRAM OF SEVENTH ANNUAL MEETING

November 6, 1937

9:30 Opening of exhibits.

10:30 Opening of general session.
Addresses by members of the Junior Academy:
"The Wilson Cloud Apparatus and Atomic Structure,"
Robert Bennet, Mishawaka
"Lithographing," Allen Hendron, Shortridge High School.

11:30 Business session—Election of officers.

1:00 General session.
"Twentieth Century Pioneering,"
Dr. Henry B. Hass, Purdue University.
Short papers by members:
"Leaf Herbaria,"
Robert Youngkin, Lew Wallace High School, Gary.
"Physical Geography in Fort Wayne High Schools."
Ronald Bishop, North Side High School.
"Performing Minor Operations on Rabbits,"
Melvin Fields, Blaine Junior H. S., Muncie.
"Rock Wool," Wayne Guernsey, Wabash High School.
"Making Lantern Slides," Opal Baughman, Marion High School.
Report on the progress of the Junior Academy in 1937 and plans for 1938. Dean Howard E. Enders, Purdue University.

MINUTES OF BUSINESS SESSION

The Indiana Junior Academy of Science held its seventh annual meeting at Manchester College, November 6, 1937, with George Hoffer, of the West Lafayette High School Science Club, presiding. The minutes of the preceding annual meeting were read and approved.

Eighteen clubs reported attendance as follows: Bloomington High School General Science Club, 2 members and Mr. Williams, Sponsor; Emhurst High School Science Club, Ft. Wayne, 20 members and Miss

Wimmer, Sponsor; North Side High School Geography Council, Ft. Wayne, 3 members and Mr. Breeze, Sponsor; North Side High School Nature Study Club, 13 members and Mr. Michaud, Sponsor; Gas City High School Science Club, 17 members and Mr. McKee, Sponsor; Lew Wallace High School Science Club, Gary, 3 members and Miss Lemon, Sponsor; Greencastle High School Science Club, 1 member and Mr. Jones, Sponsor; Shortridge High School Chemistry Club, Indianapolis, 15 members and Miss Martin, Sponsor; George Washington High School Science Club,, Indianapolis, Mr. Otto, Sponsor; Lowell High School Science Club, 5 members and Mr. Brannock, Sponsor; Marion High School Science Club, 15 members and Mrs. Mayhugh, Sponsor; Mishawaka High School Science Club, Mr. Wood, Sponsor; Mooresville High School Science Club, 1 member and Mr. Lee, Sponsor; Blaine Junior High School Science Club, Muncie, 2 members; Junior Science Club, Tipton, 5 members; Sciemus Club, Valparaiso, 18 members and Mr. Pauley, Sponsor; Wabash High School Science Club, 9 members and Mr. Krom, Sponsor; West Lafayette High School Science Club, 16 members and Miss Inskeep, Sponsor.

The following officers were elected to serve for 1938: *President*, DAVID WILLIAMS, Valparaiso; *Vice-President*, ALLEN HENDRON, Shortridge High School; *Secretary*, MARY PENROD, Marion; *Treasurer*, PAUL CORBIN, Gas City.

Miss Lola Lemon, sponsor of the Biology Club of Lew Wallace High School, Gary, was elected to the Advisory Council, taking the place of Miss Lois E. Martin, whose five-year term had expired.

Five accessions to membership in the Junior Academy were announced as follows: General Science Club, Greencastle, Frank N. Jones, Sponsor; Phi-Chem Club, Elmhurst School, Fort Wayne, Miss Ruth Wimmer, Sponsor; Phy-Chem Club, North Side High School, Fort Wayne, H. A. Thomas, Sponsor; Science Club, George Washington High School, Indianapolis, James H. Otto, Sponsor; Edison Junior Academy of Science Club, Thomas A. Edison School, Hammond, J. Harmon Bjorklund, Sponsor.

The total attendance of the meeting was about 210.

The meeting adjourned at 3:30 p.m.

Barbara Ann Badger, *Secretary*,
Shortridge High School.

Exhibits

The exhibits exceeded those of any previous year, both in number and in quality. These were displayed on the tables of two large rooms of the Biological Laboratory, and, during the hours at which they were open, the rooms were filled with club members and their parents, club sponsors, and members of the Academy.

The following exhibits are worthy of special mention:

1. Biology Club, Lew Wallace H. S., Gary, Miss Lola Lemon, Sponsor: Mounted butterflies; leaf books.

2. Chemistry Club, Shortridge H. S., Indianapolis, Miss Lois Martin, Sponsor: Photo-micrographs; rocks and minerals; synthetic rubber; forms of carbon.

3. Physics Club, Marion H. S., Mrs. Pauline Mayhugh, Sponsor: Radio transmitting exhibit.

4. Science Club, Mishawaka, H. S., Darl F. Wood, Sponsor: Gems; drawings of birds and animals; alpha-ray track apparatus; hydrochloric acid plant, working model.

5. Science Club, West Lafayette, Miss Anna Inskeep, Sponsor: Woody fungi; model boats; ant colony; stuffed birds; gem collection.

6. Nature Club, North Side H. S., Ft. Wayne, H. H. Michaud, Sponsor: Rocks; Pigeons and their breedings.

7. Sciemus Club, Valparaiso, C. O. Pauley, Sponsor: Radio transmitting exhibit; rabbit and cat skeletons; model plane.

8. Science Club, Bloomington, M. M. Wiliams, Sponsor: Gas engine; model plane; micro-projector.

JUNIOR ACADEMIES OF SCIENCE

The following is a complete list of Junior Academies of Science:

Anderson Junior High School Science Club, 13th and Lincoln Sts., Anderson.

Junior Academy of Science, Bloomington High School, Bloomington.

Tri-Science Club, Lincoln High School, Cambridge City.

Crawfordsville High School Audubon Society, 417 School St., Crawfordsville.

Biology Club, Crispus Attucks High School, West and 12th Sts., Indianapolis.

Edison Science Club, Roosevelt High School, East Chicago.

Geography Council, North Side High School, Fort Wayne.

North Side High School Nature Club, North Side High School, Fort Wayne.

Phi-Chem Club, Elmhurst School, Fort Wayne.

Phy-Chem Club, North Side High School, Fort Wayne.

Biology Club, Lew Wallace High School, 45th and Madison Sts., Gary.

Science Club, Gas City High School, Gas City.

Science Club, George Washington High School, Indianapolis.

General Science Club, Greencastle High School, Greencastle.

Science Club of Guilford High School, Guilford.

Edison Junior Academy of Science Club, Thomas A. Edison School, Hammond.

Mishawaka High School Science Club, 1202 Lincoln Way East, Mishawaka.

Science Club, Mooresville High School, Mooresville.

Hilltop Nature Study Club, North Madison High School, North Madison.

Junior Academy of Science, Junior High School, New Albany.

Science Club, Lowell High School, Lowell.

Montmorenci Junior Academy of Science, Montmorenci High School, Montmorenci.

Science Club, Blaine Junior High School, Muncie.

Science Club, Paoli High School, Paoli.

Shortridge High School Chemistry Club, 34th and Meridian, Indianapolis.

Technical High School Nature Study Club, 1500 East Michigan St., Indianapolis.
Science Club, Tipton High School, Tipton.
Union City High School Science Club, Union City.
Valparaiso High School Sciemus Club, Valparaiso.
Wabash High School Science Club, Wabash.
Washington Center Nature Lore Club, Columbia City.
West Lafayette High School Science Club, West Lafayette.

MEETINGS OF RELATED GROUPS

As in the past several years, those interested in entomology and systematic botany took advantage of the occasion of the fall meeting and held informal conferences on Saturday forenoon, November 6.

Entomology.—The meeting was called to order by Henry G. Nester, of Butler University, chairman. Fifteen to twenty were present during all or a part of the conference.

A. C. Kinsey showed specimens of cynipids and galls collected in Mexico and Central America and discussed the relationship of his studies on this group to genetics and evolution.

C. E. Gould showed living specimens of six species of roaches found in Indiana and discussed their habits. His report of the tropical brown-banded roach, *Supella supellectilium* Serv. is a new record for the state.

J. J. Davis outlined the courses in entomology now given at Purdue and spoke of research in progress. C. Benton discussed trap crops as controls for chinch bugs. G. A. Ficht described the damage to tomatoes from nematode root knot, cutworm injury to fruit buds, and the status of the European corn borer problem in Indiana. W. B. Noble described his efforts to obtain a strain of wheat resistant to the Hessian fly.

Philip Luginbill showed illustrations of the genitalia of Phyllophaga which had been photographed by a special process and discussed the distribution of the group.

G. E. Lehker announced plans for a conference of insecticide dealers and discussed his work as extension entomologist with home demonstration agents and 4-H clubs.

Philip Luginbill, Bureau of Entomology and Plant Quarantine, Box 495, Lafayette, was chosen chairman for 1938.

Systematic Botany.—The meeting was called to order by Dr. Theodore Just, chairman. About fifteen persons were present.

Ralph M. Kriebel discussed in more detail the status of *Quercus Shumardii*, which he had previously presented in the Botanical Section, and indicated its distribution in Indiana.

The botanical garden recently founded at Huntington College was brought to the attention of the group, and the discussion which followed developed numerous ideas as to how even a small garden may contribute to the efficiency of teaching and research.

Plans for a summer field meeting were discussed, and the details of arrangements were left to the new chairman.

Ralph M. Kriebel, Box 110, Newcastle, was elected chairman for 1938.

ADDITIONS TO MEMBERSHIP, 1937

Adams, Norval E., 1017 Laurel St., Elkhart.
Adams, R. A., 246 N. Sixth St., Decatur.
Beck, Ralph L., 406 S. Seventh St., Goshen.
Becker, Charles E., Station Hospital, Ft. Harrison.
Bulliet, Mrs. Mildred, 1404 N. Church St., Rockford, Illinois.
Carman, Dr. Lucille, College Hospital, North Manchester.
Caldwell, Ralph M., Dept. of Botany, Expt. Sta., Lafayette.
Clipp, Dr. Wendell V., 1104 Guilford St., Huntington.
Coats, Miss Nellie M., Indiana State Library, Indianapolis.
Cottman, Evans W., R. R. 5, Madison.
Cummins, Dr. George B., Purdue Expt. Sta., Lafayette.
Diehl, Dr. Harvey, Dept. of Chem., Purdue University, Lafayette.
Dinwiddie, William G., 1818 Central Ave., Indianapolis.
Eastwood, Dr. Floyd R., R. R. 10, West Lafayette.
Griffin, Donald T., 141 S. Meridian St., Indianapolis.
Halfast, Richard W., 625 E. South St., Carry, Pennsylvania.
Hamlett, Mrs. Iona Cuyler, 801 E. State Boulevard, Ft. Wayne.
Hamer, O. Stuart, 705 N. Sycamore St., North Manchester.
Hartzler, Dr. H. Harold, Goshen College, Goshen.
Hazel, Dr. Herbert C., R. R. 4, Bloomington.
Hobbs, Clinton H., Dept. of Biology, Purdue University, Lafayette.
Hooker, William J., 453 Littleton St., West Lafayette.
Huffman, Jasper A. Marion.
Hughes, Miss Leda Mae, 326 Audubon Rd., Indianapolis.
Hughes, Robert M., Indiana Reformatory, Pendleton.
Hunt, Prof. Virgil, Central Normal College, Danville.
Hutchison, Lee P., 716½ Rockhill St., Ft. Wayne.
Kent, John F., 198 State St., Franklin.
King, Lawrence J., 1362 Ratliff St., Richmond.
Kintner, J. Dana, 1713 N. Johnson St., South Bend.
Knight, Prof. F. B., Dept. of Psychology, Purdue University, Lafayette.
Krueger, Dr. Levi M., 6542 Monroe Ave., Hammond.
Kunz, Walden H., Indiana Technical College, Ft. Wayne.
Larson, Prof. Raymond G., Manchester College, North Manchester.
Leasure, Mrs. Nettie N., 1110 Home Ave., North Manchester.
Lohman, Dr. Marion L., Dept. of Botany, Indiana Univ., Bloomington.
Mackay, Dr. Elizabeth L., 633 Kossuth St., Lafayette.
Marchant, Guy B., Evansville College, Evansville.
Mattox, Norman T., Dept. of Biology, Purdue University, Lafayette.
Menger, Prof. Karl, Box 206, Notre Dame.
Meyer, Dr. Herbert A., Hanover.
Meyer, Dr. Jacob G., 505 E. Ninth St., North Manchester.
Miller, Dr. Donald E., Ball State College, Muncie.
Moffett, Sam M., R. R. 5, Madison.
Molter, Rev. John A., Zahn Hall, Notre Dame.
Morgan, Prof. C. L., 242 Marsteller St., Lafayette.

Morgan, Miss Ruth, 298 West St., Franklin.
Nieset, Rev. Carl F., St. Joseph College, Collegeville.
Parker, Druley, 925 E. 36th St., Indianapolis.
Patterson, Miss Virginia, 794 S. Home Ave., Franklin.
Platt, William, 240 E. King St., Franklin.
Prettyman, Prof. Robert L., 6171 Primrose Ave., Indianapolis.
Raisor, Floyd W., 816 West Powers St., Muncie.
Randall, Walter C., Akeley, Pennsylvania.
Rumple, Dr. Ora E., 11½ N. 14th St., Terre Haute.
Shipley, Prof. Edna, 2236 College Ave., Huntington.
Siegrist, Rev. U. J., St. Joseph College, Collegeville.
Smith, Marsh Hunter, 707 Hayes St., West Lefayette.
Smith, William M., 651 E. 48th St., Indianapolis.
Spangler, Miss Iva, 128 E. Foster Parkway, Ft. Wayne.
Storms, Lee B., 802 S. E. First St., Evansville.
Tapy, George Francis, 6 Mills Place, Crawfordsville.
Thomas, Harold A., 245 E. Creighton Ave., Ft. Wayne.
Tryon, Rolla M., Jr., 5432 Woodlawn Ave., Chicago.
Van Dorn, Estil B., 1053 W. 35th St., Indianapolis.
Voegelin, Mrs. Erminie W., 710 E. Washington, Greencastle.
Vonnegut, Miss Pauline, 1804 Park Ave., Indianapolis.
Waldorf, Robert O., 670 E. Jefferson St., Franklin.
Wallace, Charles F., 908 S. Governor St., Evansville.
Watts, Miss Maxine O., 2508 W. Main St., Muncie.
Welty, S. H., 1304 S. Eighth St., Goshen.
Whitney, Miss Esther, 1930 Sugar Grove Ave., Indianapolis.
Wimmer, Miss Ruth M., Mt. Etna, Huntington.
Wilson, Henry Spence, 2305 Lexington Rd., Louisville, Kentucky.
Wolfe, Ranald M., 1526 Mills Ave., Indianapolis.
Yeager, Prof. Edgar L., 503 S. Jordan Ave., Bloomington.
Young, Miss Charlotte, 601 Elm St., Urbana, Illinois.
Young, J. Emmert, 137 Pierce St., West Lafayette.
Young, Prof. James H., Marion College, Marion.

JUNIOR ACADEMIES OF SCIENCE

Phi-Chem Club, Elmhurst School, Fort Wayne.
Science Club, George Washington High School, Indianapolis.
General Science Club, Greencastle High School, Greencastle.
Edison Junior Academy of Science Club, Thomas A. Edison School, Hammond.

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